The State Medical and Pharmaceutical University "Nicolae Testemitanu"

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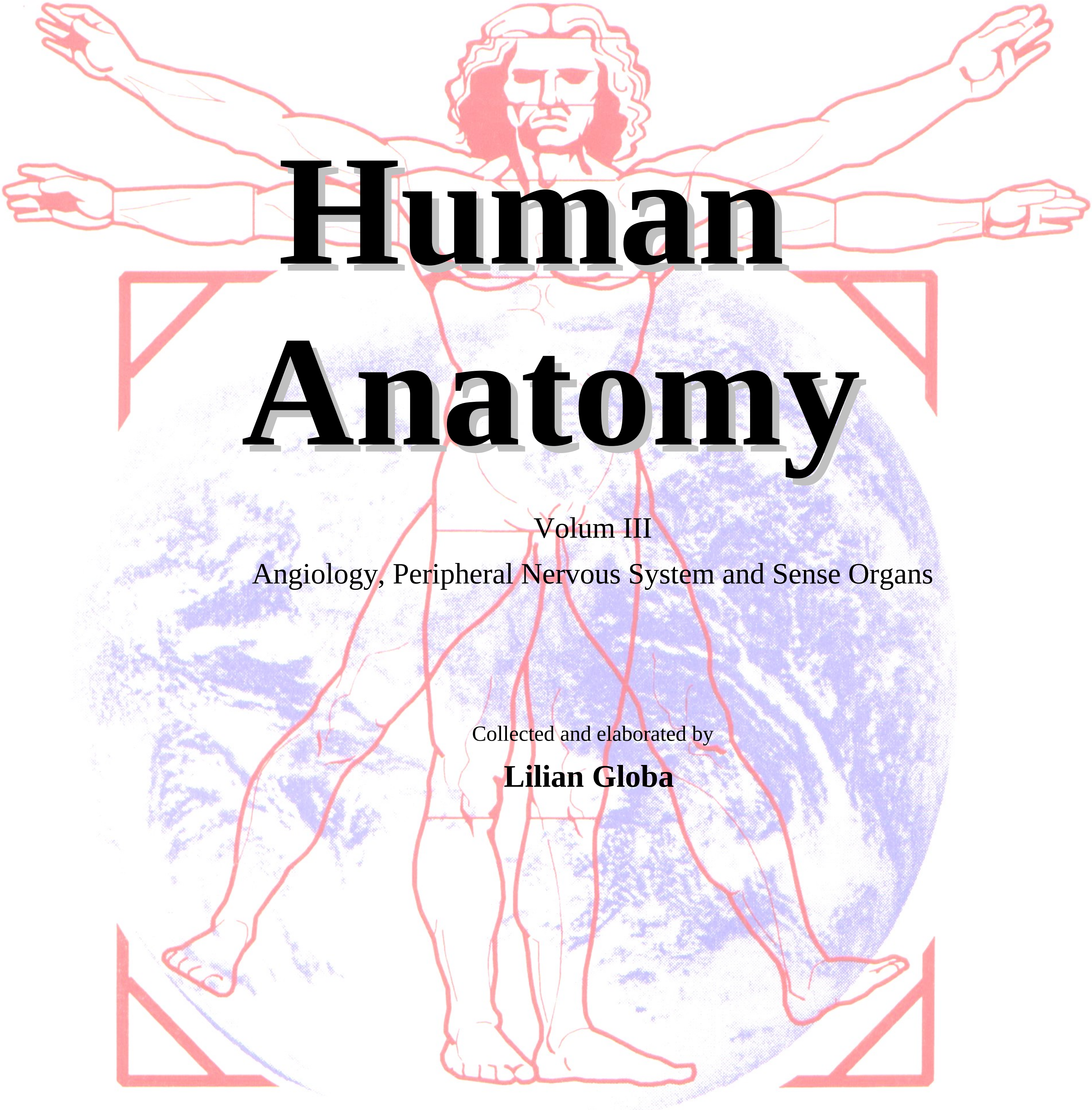

Human Anatomy

Volum III

Angiology, Peripheral Nervous System and Sense Organs

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ANGIOLOGY

The vascular system consists of a network of tubes or canals through which circulate the body's fluids, blood and lymph. From Latin **angiology** means the science of the **vessels**.

The vascular system, on the one hand, supplies the cells and tissues of the body with necessary nutrients and, on the other hand, removes and transports waste products produced by the vital activity of the cells to the kidneys, the excretory organs.

According to the character of the circulating fluid, the vascular system is classified into two systems:

1. The **blood** vascular system, made up of tubes (the heart, arteries and veins), through which the blood circulates; and
2. The **lymphatic** system, made up of tubes along which lymph, a colourless fluid, flows.

The blood vascular system

The blood vascular system (the cardiovascular system) consists of **the heart** as a central organ, and **blood vessels**, tubes of various calibres connected to it as peripheral organs. The blood vessels passing from the heart to the organs and carrying blood are called **arteries** (Gk *arteria* windpipe). Histologicaly the wall of the artery consists of three coats. The inner coat (tunica intima) is lined with endothelium and an inner elastic membrane. The middle coat (tunica media) is made up of two layers of smooth muscle fibres (an external longitudinal and an internal circular layer), which alternate with elastic fibres. The outer coat (tunica externa or adventitia) contains connective tissue fibres. The elastic elements of the arterial wall form a single elastic frame, resilient as a spring, which lends elasticity to the arteries.

Some arteries supply whole organs or parts of organs with blood. Arteries can be classified as **extraorganic** arteries, which pass outside the organ before entering it, and their continuations, **intraorganic** arteries, which branch out inside the organ. Lateral branches of a single trunk or branches of different trunks can join one another. Such a junction of vessels before their division into capillaries is called an **anastomosis** (Gk anastomoein to provide with a mouth). Most arteries form anastomoses.

The final branches of the arteries are very fine and delicate and are, therefore, classified separately as **arterioles**. They are directly continuous with the **capillaries**.

Capillaries are hair-like vessels concerned with metabolism. The capillary wall consists of a single layer of flat endothelial cells permeable to substances and gases solved in liquids. The pre-capillaries, capillaries, postcapillaries, and venules primarily perform a trophic (metabolic) function The capillaries anastomose widely among themselves and form networks continuous with the **veins**.

The veins carry blood from the organs to the heart, i.e., in a direction opposite to the flow of blood in the arteries. The walls of veins are formed in the same way as those of the arteries, except that they are much thinner and contain less elastic and muscular tissue. As a result, empty veins drop flat while the lumen of an artery in cross section gapes. The initial segments of the venous bed are **the venules**, which form directly from the capillary network and make up the roots of the veins. The venules are continuous with the veins which merge to form large venous trunks passing to the heart. The veins anastomose widely among themselves and form venous plexuses.

Blood flows through the veins because of the suction action of the heart and the thoracic cavity. Suction is created by negative pressure produced during inhalation as the result of the difference of pressure in the cavities, the contraction of striated and smooth muscles of the organs, and other factors. Venous blood is prevented from flowing backward by special **semilunar valves** in the venous walls. These valves are shaped from the folds of the endothelium with a thin layer of connective tissue inside.

As an individual grows older, the diameter of his veins and the capacity of the venous bed increase relative to the diameter of the arteries and the volume of the arterial bed.

There are also the direct connections between the tiniest arteries and veins in many organs, called **arterio-venous anastomoses**, formed in such a way that the artery divides into two branches, the larger of which branches out further into arterioles and capillaries, while the smaller merges with the veins, losing the characteristics of an arterial vessel and becoming closer in structure to a vein. As a consequence, an excess of arterial blood flowing at any moment to the tissues may be diverted to the venous bed, bypassing the capillary network. This functional adaptation saves the energy of the heart muscle and, in some cases, becomes significantly important to the function of the organ.

The arteries and attended by two veins and the large-calibre arteries by one. The exceptions to this rule, besides certain deep veins, are mainly superficial veins passing through the subcutaneous tissue that are rarely accompanied by arteries.

The walls of the blood vessels are supllied by their own fine arteries and veins called the **vasa vasorum**. The vasa vasorum branch off either from the trunk of the wall they supply with blood or from a neighbouring trunk and pass through the layer of connective tissue that surrounds the blood vessels and is more or less closely connected with their adventitia. This layer is called the sheath of the vessels (**vagina vasorum**). Embedded in the walls of the arteries and veins are many nerve endings (receptors and effectors) connected with the central and peripheral nervous system. As a result, neural regulation of the circulation is accomplished by the reflex mechanism. The blood vessels are extensive reflexogenic zones, which play a major role in the neurohumoral regulation of metabolism.

The human body is 70 per cent water, which is contained in the cells and tissues and constitutes the bulk of blood and lymph. Only one-fifth of the body's fluid is found in the vessels, the remaining four-fifths being contained in the plasma of cells and the intercellular media. In addition to the blood vascular system, the fluid microcirculatory system includes the circulation of fluid in the tissues, the serous and other cavities, and the channels of lymph transportation. Blood from the microcirculatory bed flows along of veins, and the lymph flows through the lymph vessels, which eventually join the precardiac veins. The venous blood, with the lymph that joins it, flows first into the right atrium of the heart and then into the right ventricle. From there the venous blood enters the lungs and circulates through them in a process known as lesser (pulmonary) circulation.

Lesser (pulmonary) circulation enriches the blood with oxygen in the lungs. The process begins in the **right ventricle**. **The pulmonary trunk** arises from the right ventricle; and soon branches in **two pulmonary arteries** for each lung where futher branches into capillaries. In the capillary networks the blood yields carbon dioxide in exchange for a new supply of oxygen (pulmonary respiration). The oxidized blood from the capillaries continuous to form four pulmonary veins (two veins per lung), drain into the **left atrium** of the heart.

Greater (systemic) circulation supplies all the organs and tissues of the body with nutrients and oxygen. The process begins in the **left ventricle** of the heart, from which the **aorta**, carrying arterial blood, arises. The aorta branches into the arteries, which pass to all the organs and tissues of the body and narrow into arterioles and further into capillaries. The capillaries in turn form venules and then veins. Metabolism and gas exchange between the blood and body tissues take place through the walls of the capillaries. The arterial blood flowing in the capillaries yields the nutrients and oxygen it carries and, in exchange, receives the products of metabolism and carbon dioxide (tissue respiration). The veins form two large trunks, the **vena cava superior** and **the vena cava inferior**, which end in the **right atrium** of the heart.

Another system of circulation, called the third (cardiac) circulation, services the heart itself. It begins with the **coronary arteries**, which arise from the **aorta**, and ends with the veins of the heart. These veins form **the venous sinus**, which drains into the **right atrium**, while the rest of the veins open into the atrial cavity directly.

Development of vascular system

***Phylogenesis*.**

*In the **Coelenterata** the alimentary canal develops numerous growths to facilitate the transportation of nutrients to various parts of the body, but in the **nemerteans**, a subtype of worms, three separate blood vessels develop. The **lancelet** has a closed system of blood circulation, devoid, however, of a heart; the circulation of colourless blood in the lancelet is achieved by the pulsation of the vessels themselves. The heart appears in the circulatory system of vertebrates as a pulsating organ, which gradually becomes more complicated in structure in the process of phylogenesis.*

*The heart of **fish** consists of two chambers. The chamber that receives the blood is called the atrium and is preceded by the infundibulum sinus venosus. A second chamber, called the ventricle, discharges the blood. The ventricle is followed by the infundibulum conus arteriosus. Venous blood circulates through the heart and then through the branchial arteries to the gills, where it is enriched with oxygen in branchial respiration. Pulmonary respiration and, with it, pulmonary blood circulation developed in addition to branchial respiration when amphibians emerged from the water onto dryland. The pulmonary artery in amphibians, which develops from the last branchial artery, carries blood from the heart to the lungs where the exchange of gases takes place. In connection with this, the atrium is divided by a septum into two separate atria, right and left, as a result of which the heart becomes three-chambered. Venous blood flows through the right atrium, arterial blood through the left and mixed blood through the common ventricle. Branchial circulation is typical of the larval stage of development while pulmonary circulation develops in maturity, a fact that reflects the transition from aquatic to terrestrial life.*

*When **reptiles** finally emerged onto land and pulmonary respiration completely replaced branchial respiration, pulmonary circulation developed further and two types of circulation formed: circulation in the lungs and circulation through the body. Accordingly, in reptiles the ventricle is also divided into two parts, the right and left ventricles, by an incomplete septum. In **birds** and **mammals**, man including, the ventricle is divided by a septum into two, completely separate, ventricles corresponding to the two types of circulation. Because of this, the venous and arterial bloods are fully separated: venous blood circulates in the right heart and arterial blood in the left.*

*In the process of embryogenesis, **the lymphatic system** comes into contact with the blood circulation system and becomes an additional channel for the veins. The fluid in the lymph vessels flows in the same direction as blood in the veins, i.e., from the tissues to the heart.*

Ontogenesis (Embriogenesis)

***Development of the heart. The heart** develops from two symmetrical germs, which eventually merge to form one tube in the region of the neck. The tube grows very rapidly in length and forms an S-shaped loop. The first contractions of the heart begin at a very early developmental stage when the muscular tissue can barely be discerned. In the S-shaped cardiac loop, we can distinguish an anterior arterial or ventricular section continuous with the **truncus arteriosus**, which separates into two primary aortas, and a posterior **venous or precardiac part**, into which the omphalomesenteric veins (vv. omphalo-mesentericae) drain. At this stage, the heart is unicamerate. Its division into right and left halves begins with the formation of a septum between the atria. The atrial septum arises from the posterosuperior wall of the atrium, which embraces the ventricle with its lateral protrusions (the cardiac auricles). Growing downward, the septum separates the atrium into the right and left atria so that, subsequently, the orifices of the venae cavae are located in the right atrium and those of the pulmonary veins in the left atrium. The atrial septum has an opening in the centre, foramen ovale, through which part of the blood in a foetus flows directly from the right into the left atrium. The ventricle is also divided in two by a septum, which grows upward to the atrial septum, but does not completely separate the ventricular cavities. Interventricular grooves (sulci interventriculares) appear on the outer surface according to the boundaries of the ventricular septum. Formation of the septum is completed after the truncus arteriosus is divided by a frontal septum into two trunks: **the aorta** and the **pulmonary trunk**. The septum dividing the truncus arteriosus into the two trunks continues into the ventricular cavity in the direction of the ventricular septum described above and forms the membranous part of the septum (pars membranacea septi interventriculare), hus completing the separation of the ventricular cavities. If the two parts of the interventricular septum fuse incompletely, traces of the incomplete separation of the ventricles may persist throughout life as a developmental anomaly.*

***The venous sinus** (sinus venosus) initially adjoins the right atrium. It is made up of three pairs of veins:*

the ducts of Cuvier, which carry blood from the body of the embryo, vitelline veins, which carry blood from the yolk sac, and the umbilical veins, which carry blood from the placenta. Within five weeks the orifice leading from the sinus venosus into the atrium distends widely; ultimately the wall of the sinus becomes the wall of the atrium itself. The left process of the sinus, together with the left Cuvier's duct draining into it, remains as the sinus coronarius cordis. Where it drains into the right atrium, the sinus venosus has two venous valves, the valvula venosa dextra and the valvula venosa sinistra. The left valve disappears while the right gives rise to the valvula venae cavae inferior and valvula sinus coronarii. A third atrium, either a distended venous sinus, into which all the pulmonary veins drain, or a separated part of the right atrium, may occur as a developmental anomaly.

Development of the blood vessels. Development of the arteries.

In reflection of the change from branchial to pulmonary circulation in the process of phylogenesis, the branchial arteries are the first to differentiate during ontogenesis in man; later they evolve into arteries of pulmonary and systemic circulation. In the embryo at three weeks, the truncus arteriosus, as it leaves the heart, gives rise to two arterial trunks called the ***ventral aortas*** *(right and left). They ascend, curve ventrally over the anterior gut in front of the right branchial pocket, and then return to the dorsal surface of the embryo; here they descend on both sides of the notochord and are called* ***dorsal aortas****. The dorsal aortas gradually converge in the middle segment of the embryo to form an unpaired* ***descending aorta****. With the gradual development of visceral arches in the cephalic end of the embryo, a branchial aortic arch or artery develops in each of them; these branchial arteries connect the ventral to the dorsal artery on each side. Thus, in the region of the visceral (branchial) arches, the ventral (ascending) and dorsal (descending) aortas are connected by six pairs of branchial arteries. Part of the branchial arteries and part of the dorsal aortas (the right one, in particular) ultimately reduce, while the remaining primary vessels give rise to large precardiac and arterial trunks; as pointed out above, the truncus arteriosus is divided by the frontal septum into a ventral part, from which the* ***pulmonary trunk*** *is derived, and a dorsal part, which transforms into the* ***ascending aorta****. This explains the position of the aorta behind the pulmonary trunk. In following the flow of blood from the centre to the periphery, we observe that the last pair of branchial arteries, connected in lungfish and amphibians with the lung, is transformed in man into the right and left pulmonary arteries, which are branches of the pulmonary trunk (truncus pulmonalis). The sixth branchial artery on the right remains only as a small proximal segment; the artery on the left, in contrast, continues the entire distance and forms Botallo's duct (ductus arteriosus Botalli), which connects the pulmonary trunk with the end of the aortic arch, a fact of significance for circulation in the foetus .The fourth pair of branchial arteries continues the whole distance on both sides, but gives rise to different vessels. The fourth branchial artery on the left, together with the left ventral aorta and part of the left dorsal aorta, forms the* ***arch of aorta*** *(arcus aortae).*

The proximal segment of the right ventral artery transforms into the ***brachiocephalic trunk*** *(truncus brachiocephalicus). The fourth branchial artery on the right transforms into the initial part of the right subclavian artery (a. subclavia dextra) arising from this trunk. The left subclavian artery grows from the left dorsal aorta caudal to the last branchial artery. The dorsal aortas located between the third and fourth branchial arteries obliterate; the right dorsal aorta also obliterates from the site of origin of the right subclavian artery until it merges with the left dorsal aorta.*

In the segment between the third and fourth aortic arches, both ventral aortas transform into the common carotid arteries (arteriae carotides communes); as a consequence of the transformations of the proximal segment of the ventral aorta described above, the right common carotid artery arises from the brachiocephalic trunk, while the left common carotid artery branches directly from the arcus aortae. Further, the ventral aortas transform into the external carotid arteries (arteriae carotides externae).

The third pair of branchial arteries and the dorsal aortas on the segment between the third and the first branchial arches develop into the internal carotid arteries (arteriae carotides internee). The internal carotid arteries in an adult, therefore, are located more laterally than the external arteries. The second pair of bra nchial arteries transforms into the lingual and pharyngeal arteries (arteriae linguales and pharyngeae), while the first pair transforms into the mandibular, facial, and temporal arteries. Various anomalies occur when the usual course of development is disturbed. Absence of the pulmonary trunk has been described.

Some small paired vessels passing dorsally on both sides of the neural tube are derived from the dorsal aorta. They are called dorsal segmental arteries because they arise at regular intervals into the loose *mesenchymal tissue found between the somites. In the region of the neck on both sides of the body, they are connected early by a series of anastomoses and form longitudinal vessels, the vertebral arteries.*

The buds of the upper limbs are laid down at the level of the sixth, seventh, and eighth cervical segmental arteries. One of the arteries, usually the seventh, grows into the upper limb and increases in size with the development of the limb to form the distal segment of the subclavian artery. (The proximal segment develops, as indicated above, from the fourth branchial artery on the right and from the left dorsal aorta on the left; the seventh segmental arteries become connected to these arteries.) The segmental arteries obliterate ultimately, as a result of which the vertebral arteries branch off from the subclavian vessels.

The thoracic and lumbar segmental arteries give rise to the posterior intercostal and the lumbar arteries (aa. intercostales posteriores and aa. umbales). The visceral arteries of the abdominal cavity develop partly from omphalo-mesenteric or vitelline circulation (arteriae omphalomesentericae) and partly from the aorta. The arteries of the limbs are initially laid down as loops along the nerve trunks. Some of these loops (along the femoral nerve) predominate and develop into the main arteries of the limb. Others (along the median and sciatic nerves) remain attendant to the nerves.

Development of the veins. *In the beginning of placental circulation when the heart is in the cervical region and is still not separated by septa into the venous and arterial halves, the venous system is relatively simple in structure. Large veins stretch along the body of the embryo: the* ***anterior cardinal veins*** *(right and left) in the region of the head and neck and the right and left posterior cardinal veins in the remaining part of the body. On reaching the venous sinus of the heart, the anterior and posterior cardinal veins on each side merge to form the* ***ducts of Cuvier*** *(right and left), which at first pass strictly transversely and drain into the venous sinus of the heart. Besides the paired cardinal veins, there is one unpaired venous trunk, the primary* ***vena cava inferior****, which as a small vessel also drains into* ***the venous sinus****. Thus, three venous trunks drain into the heart in this developmental stage, namely, the paired ducts of Cuvier and the unpaired primary vena cava inferior.*

Further changes in the position of the venous trunk are associated with the descent of the heart from the region of the neck and the separation of its venous section into the right and left atria. Since both ducts drain into the right atrium, after separation of the heart, the blood flow in the right Cuvier's duct occurs under more favourable conditions. As a result, an anastomosis forms between the right and left anterior cardinal veins along which the blood from the head flows into the right Cuvier's duct. As a consequence, the left Cuvier's duct ceases to function. Its walls collaps and it obliterates, except for a small segment, which becomes ***the coronary sinus of the hear****t (sinus coronarius cordis). The anastomosis between the anterior cardinal veins gradually increases and transforms into the left brachiocephalic vein, while the left anterior cardinal vein obliterates below the origin of the anastomosis.*

The right anterior cardinal vein gives rise to two vessels: the segment above the site of drainage of the anastomosis develops into the right brachiocephalic vein, and the segment below the anastomosis transforms, together with the right duct of Cuvier, into ***the superior vena cava****, which there upon collects blood from the entire cranial half of the body. A developmental anomaly in the form of two superior venae cavae may occur in underdevelopment of these anastomoses.*

The formation of the ***inferior vena cava*** *is associated with the appearance of anastomoses between the posterior cardinal veins. An anastomosis found in the iliac region drains blood from the left lower limb into the right posterior cardinal vein; as a result, the segment of the left posterior cardinal vein above the anastomosis reduces, while the anastomosis itself transforms into the left common iliac vein. The right posterior cardinal vein in the segment proximal to the anastomosis (which has become the left common iliac vein) transforms into the right common iliac vein, while the segment beginning from the merger of both iliac veins and ending at the place of drainage of the renal veins develops into* ***the secondary inferior vena cava****. The remaining section of the secondary inferior vena cava forms from the unpaired primary inferior caval vein which drains into the heart and merges with the right inferior cardinal vein where the renal veins join it (here we have the second anastomosis between the cardinal veins draining the blood from the left kidney). The inferior vena cava is, therefore, ultimately formed of two parts: the right posterior cardinal vein (prior to the place where it receives the renal veins) and the primary inferior caval vein (distal to this). Since the inferior vena cava brings blood to the heart from the entire caudal part of the body, the posterior cardinal veins become less important; their development is retarded, and they transform into the azygos vein (right posterior cardinal vein) and the* *hemiazygos and accessory hemiazygos veins (left posterior cardinal vein). The hemiazygos vein drains into the azygos vein through the third anastomosis developing in the thoracic region between the former posterior cardinal veins.*

The portal vein *is derived from the omphalomesenteric veins along which blood from the yolk sac reaches the liver. The segment of these veins between their junction with the mesenteric vein and the hepatic porta transforms into the portal vein. With the formation of placental circulation, the developing umbilical veins communicate directly with the portal vein: the left umbilical vein opens into the left branch of the portal vein and, thus, carries blood from the placenta into the liver; the right umbilical vein obliterates. Some of the blood, however, bypasses the liver through an anastomosis between the left branch of the portal vein and the end segment of the right hepatic-vein. This anastomosis, which formed with the growth of the embryo, and, consequently, with the increase in blood flow through the umbilical vein, distends considerably and transforms into* ***the ductus venosus*** *(duct of Arantius). After birth it obliterates to become* ***the ligamentum venosum*** *(Arantii).*

THE HEART

The heart (cor) is a hollow muscular organ, which receives blood from the venous trunks draining into it and pumps the blood into the arterial system. The cavity of the heart is subdivided into four chambers: two atria and two ventricles. The left atrium and the left ventricle comprise the left heart, also called the arterial heart, because of the type of blood it contains; the right atrium and right ventricle comprise the right or venous heart. Contraction of the right and left atria occurs simultaneously. The ventricles also contract simultaneously, but in regular sequence with the atria. Contraction of the walls of the heart chambers is called **systole**. Their relaxation is called **diastole**.

The heart is shaped like a slightly flattened cone. In it we distinguish an apex, a base, the anterosuperior and inferior surfaces, and the right and left borders, separating these surfaces.

The rounded apex of the heart (apex cordis) faces downward, forward, and to the left, reaching the fifth intercostal space 8-9 cm to the left of the midline; the apex is formed by the left ventricle. **The base of the heart** (basis cordis) faces upward, backward, and to the right. It is formed by the atria and, in front, by the aorta and pulmonary trunk. The opening of the superior vena cava into the heart is in the upper right angle of the rectangle formed by the atria, that of the inferior vena cava in the lower right angle. The two right pulmonary veins enter immediately to the left. The two left pulmonary veins enter on the left border.

The anterosuperior, or sternocostal surface of the heart (facies sternocostalis) faces forward, upward, and to the left and is located behind the body of the sternum and the cartilages of the third to sixth ribs. **The atrioventricular groove** (sulcus coronarius) passing transversely to the longitudinal heart axis and separating the atria from the ventricles, divides the heart into an upper area formed by the atria and a larger, lower area formed by the ventricles. **An anterior interventricular groove** (sulcus interventricularis anterior) on the sternocostal surface passes on the borderline between the ventricles; the greater part of the anterior surface is formed by the right ventricle, the smaller part by the left ventricle.

The inferior or diaphragmatic surface (facies diaphragmatica) connects the central tendon at the diaphragm. **An inferior interventricular groove** (sulcus interventricularis posterior) runs on the surface and separates the surface of the left ventricle (larger) from the surface of the right ventricle (smaller). The lower ends of the anterior and inferior interventricular grooves of the heart fuse to form **the incisure of the apex of the heart** (incisura apicis cordis) on the right heart border immediately to the right of the apex. The right and left borders of the heart differ in configuration: the right is sharp, while the left border, less sharp because the wall of the left ventricle is thick, is rounded.

It is considered that the size of an individual's heart is equal to the size of his fist. On the average, the heart is 12-13 cm in length and no wider than 9-10.5 cm. The average antero-posterior dimension is 6-7 cm. The male heart weighs 300 g, on the average (1/215 of total body weight), and a female heart, 220 g (1/250 of total body weight).

Chambers of the heart

The atria are blood-receiving chambers. **The ventricles**, in contrast, pump blood from the heart into the arteries. The right and left atria are separated by **a septum** (septum interatriale) just as the right and left ventricles are. The right atrium and right ventricle communicate by **the right atrioventricular orifice** (ostium atrioventriculare dextrum) and the left atrium with the left ventricle by **the ostium atrioventriculare sinistrum**. Through these openings blood is directed from the atrial cavities during their contraction into the cavities of the ventricles.

The right atrium

The right atrium (atrium dextrum) is shaped like a cube. In the back it receives the superior vena cava above and the inferior vena cava below. In front, the atrium is continuous with a hollow process, **the auricle of right atrium** (auricula dextra). The right and left auricles embrace the base of the aorta and the pulmonary trunk. **The atrial septum** (septum interatriale) is set obliquely. It passes to the back and to the right from the anterior wall so that the right atrium is located to the right and anteriorly, and the left atrium to the left and posteriorly. The inner surface of the right atrium is smooth except for a small frontal area and for the inner surface of the auricle where **the pectinate muscles** (musculi pectinati) form a series of small vertical columns. Superiorly the pectinate muscles are continuous with a crest (crista terminalis), to which the sulcus terminalis corresponds on the external surface of the atrium. This sulcus points to the site where the primary sinus venosus is connected with the atrium of the embryo. On the septum separating the right atrium from the left is **an oval depression** (fossa ovalis), which is bounded superiorly and anteriorly by a raised edge, annulus ovalis (**limbus fossae ovalis**). This depression is a remnant of the foramen ovale through which the atria communicate during the intrauterine period. The foramen ovale may persist throughout life (in one-third of all cases). On the posterior wall between the orifices of the superior and inferior venae cavae is a small ridge, **intervenous tubercle** (tuberculum intervenosus) to the back of the superior part of the fossae ovalis. This ridge is thought to direct the flow of blood in the embryo from the superior vena cava into the right atrioventricular orifice.

A fold of vena cava inferior (valvula venae cavae inferioris) stretches from the inferior margin of the orifice of the inferior vena cava to the limbus fossae ovalis. This fold is of vital importance for the embryo because it directs blood from the inferior vena cava through the foramen ovale into the left atrium. Below this valve, between the openings of the inferior vena cava and the right atrioventricular orifice, the sinus coronarius cordis, which collects blood from the veins of the heart, drains into the right atrium; moreover, small veins of the heart drain independently into the right atrium. **Their small openings** (foramina venarum minimarum) are scattered over the surface of the atrial walls. A small endocardial fold (**valvula sinus coronarii**) is found close to the opening of the venous sinus. In the inferoanterior section of the atrium, the wide right atrioventricular orifice (ostium atrioventriculare dextrum) leads into the cavity of the right ventricle.

The left atrium

The left atrium (atrium sinistrum) adjoins posteriorly the descending aorta and the oesophagus. Two pulmonary veins drain into it from each side. **The auricle of the left atrium** (auricula sinistra) protrudes anteriorly, passing around the left side of the aorta and pulmonary trunk. The auricle contains pectinate muscles. In the inferoanterior section, an oval-shaped, **left atrioventricular orifice** (ostium atrioventriculare sinistrum) leads into the cavity of the left ventricle.

The right ventricle

The right ventricle (ventriculus dexter) is shaped like a triangular pyramid. The base of the pyramid directed upward makes up the right atrium, with the exception of the upper left angle where the pulmonary trunk, truncus pulmonaris, leaves the right ventricle. The cavity of the ventricle is subdivided into two parts: the section nearest the right atrioventricular orifice, **the corpus**, and an anterosuperior section close to the orifice of the pulmonary trunk, the conus arteriosus, which is continuous with **the pulmonary trunk,** soon divided into two pulmonary arteries.

The right atrioventricular orifice leading from the cavity of the right atrium into the cavity of the right ventricle is supplied with **a tricuspid valve** (valva atrioventricularis dextra s. valva tricuspidalis), which prevents the return of blood into the atrium during systole; the blood flows into the pulmonary trunk. Three cusps of the valve are designated, according to their location, as **the cuspis anterior, cuspis posterior,** and **cuspis septalis**. The free margins of the cusps face into the ventricle. Fine **tendinous threads** (chordae tendineae) are attached to them. At their other ends these chordae are attached to the apices of **the papillary muscles** (musculi papillares). The papillary muscles are conical muscular projections, with the apex projecting into the cavity of the ventricle and the base continuous with the ventricular wall. There are usually **three papillary muscles** in the right ventricle; **the anterior muscle**, the largest, gives rise to tendinous chords attached to the anterior and posterior cusps of the tricuspid valve; **the** smaller **posterior muscle** sends tendinous chords to the posterior and septal cusps, and, finally, a third inconstant **septal papillary muscle** usually sends tendinous chords to the anterior cusps. If this muscle is absent, the chords arise directly from the ventricular wall.

The wall of the right ventricle is smooth in the region of the conus arteriosus, but elsewhere there are inwardly projecting **muscular trabeculae** (trabeculae carneae). Between the longitudinal trabeculae lies a series of transverse ridges, as a result of which a network of trabeculae is produced.

Blood from the right ventricle enters the pulmonary trunk through an orifice, the **ostium trunci pulmonalis**, supplied with a valve, **the valva trunci pulmonalis**, which prevents the return of blood from the pulmonary trunk into the right ventricle during diastole. The valve is composed of three semilunar cusps called **the semilunar valvulae**. One of them is attached to the anterior third of the circumference of the pulmonary trunk (**valvula semilunaris anterior**) and the other two to the posterior section of the circumference (**valvulae**

semilunares dextra and **sinistra**). A small nodule, **the nodulus valvulae semilunaris**, is found in the middle of the free inner border of each valve; on each side of this nodule there are thin marginal segments of the valve called the lunulae valvulae semilunares. The nodules make the valves close more tightly.

The left ventricle

The left ventricle (ventriculus sinister) has a conical shape. The thickness of its walls is two or three times more that of the wall of the right ventricle (10-15 mm, and 5-8mm, respectively). This difference is explained by the muscular layer and by the greater workload of the left ventricle (**systemic circulation**) compared with that of the right ventricle (**pulmonary circulation**). The walls of the atria are, nevertheless, thinner than those of the ventricles (2-3 mm), in accordance with their function. The trabeculae carneae are thinner and more numerous in the left than in the right ventricle, and there are more of them on the diaphragmatic wall and in the region of the apex. The upper part of the sternocostal surface and the septum, in comparison, are relatively smooth. The orifice leading from the cavity of the left atrium into the left ventricle, **the ostium atrioventriculare sinistrum**, is oval, and it is supplied with **a bicuspid valve** (valva atrioventricularis sinistra (**mitralis**) s. bicuspidalis). The smaller cusp is to the left and back (**cuspis posterior**), the larger to the right and front (**cuspis anterior**). The free margins of the valve face into the ventricular cavity; the chordae tendineae are attached to them. There are two **papillary muscles, anterior** and **posterior**, in the left ventricle. They are much larger than the papillary muscles in the right ventricle. Each muscle sends tendinous threads to both cusps of the mitral valve. The aortic orifice is called **ostium aortae**, and the part of the ventricle closest to it is called the infundibulum (**conus arteriosus**).

The aortic valve (valva aortae) is similar in structure to the valve of the pulmonary trunk. One of the valvules, the valvula semilunaris **posterior** occupies the posterior one-third of the aortic circumference (according to the Paris Nomina Anatomica (PNA), the term "valva" is used to designate a valve as a whole (e.g., ileocolic, semilunar, etc.), while the term "valvula" designates its component valves or cusps). The other two, **the valvulae semilunares dextra** and **sinistra**, occupy the right and left sides of the orifice. The nodules on their free margins, the **noduli semilunarium aortae**, are more conspicuous than those on the valves of the pulmonary trunk; **lunulae semilunarium aortae** are also present.

The ventricular septum (septum interventriculare) consists mainly of muscle tissue (**pars muscularis**), except for the uppermost area where it is formed of fibrous tissue covered on both sides with the endocardium (**pars membranacea**). In distinction from the muscular part, the membranous part arises not from the ventricular wall, but from the septum of the truncus arteriosus and corresponds to a section of the incompletely developed inter-ventricular septum of animals. Anomalies and defects in the development of this septum are often encountered in man.

Structure of the heart walls

The walls of the heart are made up of **three layers**: an inner layer, **the endocardium**, a middle layer, **the myocardium**, and an outer layer, **the epicardium**, which is the visceral membrane of the pericardium. The thickness of the cardiac walls consists mainly of the middle layer, the myocardium, made up of muscle tissue. The outer layer, the epicardium, is the visceral lining of the serous **pericardium**. The inner layer, the endocardium, lines the heart cavities.

Although the myocardium, or the muscle tissue of the heart, is cardiac striated, it differs from the skeletal muscles in that it consists not of symplasts, but of a network of contiguous, mononuclear cells joined to form fibres.

Two layers are distinguished in the heart musculature: the muscular layers of the atrium and the muscular layers of the ventricles. The fibres of both arise from **two fibrous rings** (anuli fibrosi) one of which surrounds the right atrioventricular orifice and the other, the left atrioventricular orifice. The fibres of the atrium contract separately from the ventricles. **A superficial** and **a deep muscular** layer are distinguished **in the atria**: the superficial layer consists of circular or transverse fibres, whereas the deep layer is made up of longitudinal fibres arising from the fibrous rings and encircling the atrium like a loop. The large venous trunks draining into the atria are surrounded by circular fibres like sphincters. The fibres of the superficial layer encircle both atria; the deep fibres are separate in each atrium.

The musculature of the ventricles is even more complex. **Three layers** can be distinguished in it. A thin **superficial layer** is composed of longitudinal fibres which arise from the right fibrous ring and descend obliquely, passing also onto the left ventricle; on the heart apex, they form a whorled mass (**vortex cordis**), making loops in the depths of the muscle and forming the **longitudinal inner layer**; the upper ends of the fibres of this layer are attached to the fibrous rings. The fibres of the middle layer, between the longitudinal outer and inner layers, are more or less **circular**. In contrast to the fibres of, the superficial layer, however, they do not pass from one ventricle to the other but are independent components of each ventricle.

The epicardium covers the outer surface of the myocardium and is an ordinary serous membrane lined by the mesothelium. The underlying structures can be seen through the transparent epicardium: the middle layer of the heart (myocardium), vessels, nerves, and subepicardial fatty tissue. The latter lies along the coronary and interventricular grooves of the vessels.

The endocardium forms the lining of the inner surface of the heart cavities. It is made up, in turn, of a layer of connective tissue rich in elastic fibres and smooth muscle cells, a layer of connective tissue over the first layer with an admixture of elastic fibres, and an inner endothelial layer, the presence of which distinguishes the endocardium from the epicardium. In origin, the endocardium corresponds to the vascular wall, while its three layers correspond to the three vascular coats. All the heart valves are folds of the endocardium.

The conducting system

An important role in the rhythmic work of the heart and in the coordination of the activity of the musculature of the separate heart chambers is played by the conducting system of the heart. Although the atrial musculature is separated from the ventricular musculature by fibrous rings, the two musculatures are, nevertheless, connected **by the conducting system,** which is composed of a complex of special cardiac muscles fibres (fibres of Purkinje). The cells of these muscle fibres are poor in myofibrils but rich in sarcoplasm. The following nodes and bundles are distinguished in the conducting system:

1. **The sinoatrial node** (nodus sinuatrialis) or Keith-Flack's sinoatrial bundle is located in an area of the right atrial wall in sulcus terminalis, between the superior vena cava and the right auricle. It is connected with the musculature of the atria and is important for their rhythmic contraction. The atria are, therefore, connected to each other by the sinoatrial bundle and to the ventricles by the atrioventricular bundle. Stimulation from the right atrium is usually conducted from the sinoatrial node to the atrioventricular node.

2. **The atrioventricular bundle** (fasciculus atrioventricularis) arises as a thickening of **the atrioventricular node**, nodus atrioventricularis (the node of Aschoif and Tawara), lying in the wall of the right atrium near the cuspis septalis of the tricuspid valve. The fibres of the node are directly connected with the atrial musculature and continue into the septum between the ventricles as **the atrioventricular bundle of His**. In the septum between the ventricles, the bundle of His divides into **right and left crura** (crus dextrum and crus sinistrum), which pass into the walls of the respective ventricles and give off branches under the endocardium in the musculature. The atrioventricular bundle is significant in the work of the heart since it conducts the wave of contraction from the atria to the ventricles that regulates the rhythm of the systole of the atria and ventricles.

The sinoatrial and atrioventricular bundles should be considered a neuromuscular complex, which is connected with all parts of the heart and with the central nervous system.

The vessels of the heart

The arteries of the heart, the **right** and **left coronary arteries** (a. coronaria dextra and a. coronaria sinistra) arise from **the bulbus aortae** below the superior margins of the semilunar valves. As a result, during systole the entrance to the coronary arteries is closed by the valves, while the arteries themselves are compressed by the contracted heart muscles. As a consequence, the supply of blood to the heart diminishes during systole; **blood enters the coronary arteries during diastole** when the openings of these arteries in the orifice of the aorta are not closed by the semilunar valves.

The right coronary artery (a. coronaria dextra) arises from the aorta corresponding to the right semilunar valvule and passes between the aorta and the auricle of the right atrium laterally. From there it curves around the right border of the heart in the coronary sulcus and passes over to its posterior surface. Here it is continuous with the interventricular branch (ramus interventricularis posterior). Along the right margine is located **marginal branch**. The interventricular branch descends in the posterior interventricular sulcus to the heart apex where it anastomoses with the branch of the left coronary artery.

The branches of the right coronary artery vascularize: the right atrium, part of the anterior and the entire posterior wall of the right ventricle, a small area of the posterior wall of the left ventricle, the interatrial septum, the posterior one-third of the interventricular septum, the papillary muscles of the right ventricle, and the posterior papillary muscle of the left ventricle.

The left coronary artery (a. coronaria sinistra) arises from the aorta at the left similunar valvule and also lies in the coronary sulcus to the front of the left atrium. Between the pulmonary trunk and the left auricle, it gives off two branches: a thinner, **anterior interventricular branch** (ramus interventricularis anterior) and a larger, left **circumflex branch** (ramus circumflexus). The first descends along the anterior interventricular sulcus to the heart apex where it anastomoses with the branch of the right coronary artery. The second is a continuation of the main trunk of the left coronary artery; it curves around the heart from the left side in the coronary sulcus and is also connected with the right coronary artery. As a result, **an arterial ring** forms along the whole coronary sulcus, which is located in **a horizontal plane** and from which branches to the heart rise perpendicularly. The ring is a functional adaptation for the collateral circulation of the heart. The branches of the left coronary artery vascularize the left atrium, the entire anterior and the greater part of the posterior left ventricular wall, part of the anterior wall of the right ventricle, the anterior two-thirds of the interventricular septum, and the anterior papillary muscle of the left ventricle.

Developmental variants of the coronary arteries may occur, as a result of which the correlations of the blood-supply channels differ. Three forms of blood supply to the heart are distinguished from this standpoint: **uniform** blood supply, with similar development of both coronary arteries, **left-coronary blood supply**, and **right-coronary blood supply.**

In addition to the coronary arteries, arteries reach the heart from the bronchial arteries, from the inferior surface of the aortic arch near the arterial ligament. These arteries must be considered during operations on the lungs and oesophagus since injury to them would adversely affect blood supply to the heart.

The intraorganic arteries of the heart. According to the four heart chambers, the coronary arteries and their large branches give off arteries to the atria (**aa. atriales**) and their auricles (**aa. auriculares**), the ventricles (**aa. ventriculares**), and the septa between them (**aa. septi anterior** and septi **posterior**). On penetrating the thickness of the myocardium, they branch out according to the number, location, and structure of its layers: first in the outer layer, then in the middle layer (in the ventricles), and finally in the inner layer, after which they penetrate the papillary muscles (aa. papillares) and even the atrioventricular valves. The intramuscular arteries, in each layer follow the course of the muscle bundles and anastomose in all the layers and sections of the heart.

The walls of some of these arteries have a strongly developed layer of smooth muscles, which contract to close the lumen of the vessel completely. The arteries are, therefore, called "closing" arteries. Temporary spasm of these arteries may lead to the cessation of the flow of blood to the given area of the heart muscle and cause myocardial infarction. Some branches pass through muscular fibers, that also compress them during ventricular systole (muscular bridge). A case of an accessory coronary artery of the heart arising from the pulmonary trunk has been described.

The veins

The veins of the heart drain not into the venae cavae, but directly intothe heart cavity. They arise as networks in different layers of the wall of the heart. The venous bed significantly predominates over the arterial bed. The intramuscular veins are found in all myocardial layers. They are attendant to the arteries and follow the course of the muscle bundles. Small arteries (those up to the third order) are attended by paired veins, larger arteries by a single vein. Venous blood drains along three routes into:

1) the venous sinus;

2) the anterior veins of the heart; and

3) the small veins (Thebesius-Vieussens) draining directly into the right heart.

The number of these veins is greater in the right than in the left heart, as a consequence of which the coronary veins are better developed on the left. The venous system is genetically and functionally similar throughout the heart. The Thebesius veins are predominant in the walls of the right ventricle in the small drainage along the system of coronary sinus veins. This is evidence of their important role in the redistribution of venous blood in the region of the heart.

1. Veins of **the system of the coronary sinus**, sinus coronarius cordis. The sinus is a remnant of the left Cuvier's duct and is located in the posterior section of the coronary sulcus of the heart between the left atrium and the left ventricle. Its thicker right end opens into the right atrium near the inter-ventricular septum, between the valvule of the inferior vena cava and the atrial septum. The following veins drain into the coronary sinus:

a) **v. cordis magna** arises at the heart apex, ascends in **the anterior interventricular** sulcus of the heart, turns to the left and, curving over the left side of the heart, is continuous with the coronary sinus;

b) **v. posterior ventriculi sinistri** is one or more small venous trunks on the posterior surface of the left ventricle which drain into the coronary sinus or into v. cordis magna;

c) **v. obliqua atrii sinistri** is a small branch on the posterior surface of the left atrium (a remnant of the embryonic v. cava superior sinistra), which arises from the pericardial fold containing a cord of connective tissue, the plica venae cavae sinistrae, also a remnant of the left vena cava;

d) **v. cordis media** lies in the **posterior interventricular sulcus** and, on reaching the transverse sulcus, drains into the coronary sinus; and

e) **v. cordis parva**, a thin branch in the right half of the transverse sulcus, usually drains into the v. cordis media where the latter reaches the transverse sulcus.

2. **The anterior cardiac veins**, vv. cordis anteriores, small veins on the anterior surface of the right ventricle, drain directly into the cavity: of the right atrium.

3. **The smallest cardiac veins**, vv. cordis minimae, are very small venous trunks, which do not appear on the heart's surface but, having formed from capillaries, drain directly into the cavities of the atria and ventricles.

Lymph drenage and innervations of heart

The lymphatics

Three networks of **lymph capillaries** are distinguished in the heart: under the endocardium, in the myocardium, and under the epicardium. Two main lymph collectors of the heart form among the drainage vessels. The **right collector** originates at the beginning of the posterior interventricular sulcus; it receives lymph from the right ventricle and atrium and reaches the left superior anterior mediastinal nodes located on the aortic arch near the origin of the left common carotid artery. The **left collector** forms in the coronary sulcus near the left border of the pulmonary trunk, where it receives vessels carrying lymph from the left atrium, the left ventricle, and partly from the anterior surface of the right ventricle; then it stretches to the tracheobronchial or tracheal nodes or to the nodes of the root of the left lung.

Both collectors drain into the nodes of the anterior mediastinum, into the **left tracheal or tracheobronchial nodes.**

The nerves

The nerves innervating the heart musculature, with its distinctive structure and function, are complex and form numerous plexuses. The whole nervous system of the heart is composed of:

1) arriving nerve trunks;

2) plexuses in the heart itself; and

3) plexuses connected with those of the ganglionic fields.

The nerves of the heart are divided according to function into four types (I.P. Pavlov): decelerating, accelerating, diminishing, and intensifying. Morphologically they are part of the vagus nerve and the sympathetic trunk. The **sympathetic nerves** (mainly the postganglionic fibres) branch off from the **upper three cervical** and **upper five thoracic** sympathetic ganglia: n. cardiacus cervicalis superior from the ganglion cervicale superius; n. cardiacus cervicalis medius from the ganglion cervicale medium; n. cardiacus cervicalis inferior from the ganglion cervicale inferius or ganglion cervicothoracicum s. ganglion stellatum, and nn. cardiaci thoraciii from the thoracic ganglia of the sympathetic trunk. When there are four cervical ganglia, a fourth rt. cardiacus cervicalis exists; in individuals with two cervical ganglia, there are only two cervical cardiac nerves.

The **cardiac branches** of the vagus nerve (**parasympathetic**) arise from its cervical (rami cardiaci superiores) and thoracic (rami cardiaci medii) parts and from n. laryngeus recurrens vagi (rami cardiaci inferiores). The arriving nerves are composed of two groups, superficial and deep. The superficial group adjoins the carotid and subclavian arteries in the superior segment and the aorta and pulmonary trunk in the inferior segment. The deep group, composed mainly of vagal branches, lies on the anterior surface of the lower third of the trachea. These branches come in contact with the lymph nodes in the region of the trachea. If these nodes become enlarged, e.g., in pulmonary tuberculosis, they may compress the vagal branches, which lead to changes in the heart rhythm. Two nerve plexuses form from the sources mentioned: a **superficial plexus**, plexus cardiacus superficialis, between the arch of the aorta (under it) and the bifurcation of the pulmonary trunk; a

deep plexus, plexus cardiacus profundus, between the arch of the aorta (behind it) and the bifurcation of the trachea.

These plexuses are continuous with the **plexus coronarius dexter** and the **plexus coronarius sinister** surrounding the vessels of the same name, as well as with the plexus located between the epicardium and myocardium. The latter plexus gives off intraorganic branches of nerves. Numerous groups of ganglionic cells, nerve ganglia, are contained in the plexuses. **Six intracardiac plexuses** located under the epicardium are distinguished: **two anterior plexuses** (the first on the left, the second on the right) descend along the aorta and pulmonary trunk to the ventricles; there are **two posterior** plexuses, one on the border between the atria (the third) and the other on the posterior wall of the ventricles (the fourth); the **fifth plexus** is on the anterior wall of the atria and the **sixth** on the posterior wall of the left atrium. All plexuses are attended by ganglionic fields which occupy, as do the plexuses, a definite territory, although the number of ganglia forming them, their size, and their interrelationship often vary. The ganglionic fields are most highly developed in man.

The afferent fibres arise from the receptors and, together with the efferent fibres, pass to the vagus and sympathetic nerves.

The pericardial sac

The pericardial sac (pericardium) is a closed serous sac, in which **two layers** are distinguished: an outer **fibrous layer**, the pericardium fibrosum, and an inner **serous layer**, the pericardium serosum. The fibrous pericardium merges with the adventitia of the large vessels and attaches anteriorly to the inner surface of the sternum by short cords of connective tissue called **ligamenta sternopericardiaca**.

The serous pericardium is, in turn, divided into two layers: **a visceral layer** or the epicardium mentioned above, and **a parietal layer**, which fuses with the inner surface of the fibrous pericardium and lines it. A slit-like serous cavity (cavum pericardii) containing a small amount of **serous fluid** (liquor pericardii) exists between the visceral and parietal layers. On the trunks of large vessels close to the heart, the visceral and parietal layers are continuous. An intact pericardium is shaped like a cone, whose base fuses with the central tendon of the diaphragm, while the blunted apex is directed upward and embraces the roots of the large vessels. The pericardium is directly attached to the mediastinal pleura on both sides. The posterior surface of the pericardial sac adjoins the oesophagus and the descending aorta. The aorta and pulmonary trunk are surrounded on all sides by a common pericardium so that when the pericardial sac is open a finger can be passed around them. The passage behind the aorta and pulmonary trunk is called **the transverse sinus of the pericardium** (sinus transversus pericardii). The venae cavae and the pulmonary veins are only partly covered with the serous layer and, therefore, a finger cannot be passed around them. The space bounded below and to the right by the inferior vena cava and above and to the left by the left pulmonary veins is **the oblique sinus of the pericardium** (sinus obliques pericardii).

The topography of the heart

The heart is located asymmetrically in the inferior middle mediastinum. Its greater part is to the left of the midline, and only the right atrium and both venae cavae are to the right. The long axis of the heart extends obliquely downward from right to left and from back to front, forming an angle of about 40 degrees with the body axis. The heart is thus rotated so that the right venous part lies more to the front and the left arterial part more to the back.

The greater part of **the anterior surface** of the heart and pericardium, **sternocostal surface** (facies sternocostalis) is covered by the lungs, whose anterior borders, together with the corresponding part of both pleuras, extend in front of the heart and separate it from the anterior thoracic wall, except for one area of the anterior surface of the heart, which by the pericardium attaches to the sternum and cartilages of the fifth and sixth left ribs.

The heart borders are projected onto the chest wall as follows: **the apex** is located in the fifth intercostal space 1-1,5 cm from the left medio-clavicular (mamillary) line toward the midline. **The superior border** of the cardiac projection passes on a level with the superior margin of the third costal cartilages. **The right border** of the heart passes 2-3 cm to the right of the right sternal border between the third and fifth ribs; **the inferior border** stretches transversely from the cartilage of the fifth right rib to the heart apex; **the left border** passes from the cartilage of the third rib to the heart apex.

The orifices of the ventricles (the orifices of the aorta and pulmonary trunk) are on the level of the left third costal cartilage: **the orifice of the pulmonary trunk** is at **the sternal end of this cartilage**, while **the aortic orifice** is behind the sternum and slightly to the right. **Both atrioventricular orifices** are projected on a straight line passing on the sternum from the third left to the fifth right intercostal space.

Auscultantion (hearing) of heart valves

The mitral valve (1st point) is heard at the heart apex (5th intercostals space 1-1,5 cm from the left medio-clavicular (mamillary) line toward the midline). The aortic valves can be heard (2nd point) at the sternal border (2 cm from sternum) in the right second intercostal space. The valves of the pulmonary artery can be heard (3rd point) in the second intercostal space to the left of the sternum (2 cm from sternum). And the tricuspid valve is heard at the sternum, to the right and opposite the fifth costal cartilage (at the base of xyphoid procesus). Additional for aortic valves, 5th point of auscultation (Botckin-Erb) is localized between 1st and 2nd points of auscultation.

According to the latest data, the heart, is not a unique pump that pushes blood along capillaries stretching thousands of kilometers, has intermediate "substations", which help the heart. The skeletal muscles are also organs, which provide themselves with blood independently. Every muscle is capable, of course, of contracting for locomotion and of generating heat. Each may also serve as a suction-pressure micropump. Experiments have shown that an isolated muscle can "propel" blood along an artificially closed circuit. The muscle, therefore, is now referred to as a peripheral "heart". More than six hundred such pumps, "helpers of the heart", exist in the human body. Without them the principal circulation "power-house" in the human body would fail under the damage.

Anatomy of the cardiovascular system in alive human beings (radioangiology)

Radiological examination of the heart of a live subject is conducted mainly by röentgenoscopy of the chest in various positions. As a result, the heart can be examined from all sides, and information can be gathered about its shape, size, and condition as well as about the condition of its parts (ventricles and atria) and the large vessels connected with them (aorta, pulmonary trunk, venae cavae).

The subject is usually examined in an anterior position with the rays directed sagittally and dorsoventrally. In this position, an intensive, dark shadow called the median shadow, appears between two light, pulmonary fields. The shadow is produced by the shadows of the thoracic spinal segment and the sternum overlapping the shadows of the heart, the large vessels, and the organs of the posterior mediastinum located between them. This median shadow, however, appears as the profile of the heart and the large vessels because the other structures mentioned above (the spine, sternum, and so on) are usually not outlined within the limits of the cardiovascular shadow. Normally this shadow extends both on the right and the left beyond the spinal and sternal borders, which become visible in the anterior position only in pathological cases (spinal deformity, displacement of the cardiovascular shadow, and so forth). The upper part of the median shadow has the shape of a wide band, which widens as it moves downward and to the left and becomes the shape of an irregular triangle with the base facing downward. The lateral outlines of this shadow have bulges separated by depressions, These bulges are called **arches**. They correspond to those parts of the heart and the large vessels connected with it which form the borders of the cardiovascular silhouette.

A clear idea of the general topography of the heart is essential in examination of the heart in a particular individual. In the anterior position the lateral contours of the cardiovascular shadow have **two arches on the right** and **four on the left.**

The inferior arch is clearly seen on the **right contour**; it corresponds to the **right atrium**. The slightly convex, **superior arch** is medial to the inferior arch and is formed by the **ascending aorta** (in the lower section) and **the superior vena cava** (in the upper section). This arch is called the vascular arch (in cadavers and in a supine, live subject, the arch is formed only by the superior vena cava). Still another small arch is seen above the vascular arch; it passes upward and laterally to the clavicle and corresponds to the vena anonyma. Below, the arch of the right atrium forms a sharp angle with the diaphragm. A vertical strip of shadow can be seen in this angle at the peak of deep inspiration when the diaphragm descends; it corresponds to the inferior vena cava.

On the **left contour**, the highest (**first) arch** corresponds to the arch and the descending part of the aorta, **the second arch** to the pulmonary artery, **the third** to the left atrium (left auricle), and **the fourth** to the left ventricle. The bulge formed by the auricle of the left atrium is often poorly demonstrated, in which case only three arches are distinguished. The left atrium, whose greater part is located on the posterior surface, does not form a border when the rays are directed dorso-ventrally and is therefore invisible in the anterior position. For the same reason the contours of the right ventricle on the anterior surface are not demonstrated; moreover, its shadow merges below with the shadows of the liver and the diaphragm. The junction between the arch of the left ventricle and the inferior outline of the heart silhouette is recorded radiologically as the apex of the heart.

In the regions of the second and third arches, the left contour of the heart silhouette appears as a depression or constriction called the "waist" of the heart. The "waist" seems to separate the heart itself from the vessels connected to it, which form the vascular bundle.

In studying the topography of the heart of a living person, **the skeletopy** of the above described X-ray arches of the cardiovascular shadow should be taken into cosideration. The vascular arch on the right side is on a level with the second intercostal space; the arch of the right atrium occupies the region of the third and fourth intercostal spaces. The first arch on the left (the arch of the aorta and the beginning o the descending segment) is on a level with the first intercostal space. The second (pulmonary artery) and third (left atrial auricle) arches are on a level with the second intercostal space; the fourth arch (left ventricle) occupiethe third, fourth and fifth intercostal spaces.

The shape and position of the heart

The shape and position of the heart depend on constitution, sex, age, various physiological states, and other factors, as a result of which there is no standard heart type. According to shape and position, three heart types are distinguished:

1. **Oblique** (most frequent). The cardiovascular shadow is triangular; the "waist" of the heart is only slightly outlined. The angle of inclination ranges between 43 and 48 degrees.
2. **Horizontal**. The position of the cardiovascular shadow is almost horizontal; the angle of inclination is 35 to 42 degrees; the "waist" is sharply outlined. The shadow of the horizontal heart is shorter and wider than that of the oblique heart.
3. **Vertical**. The silhouette of the cardiovascular shadow is almost vertical ("upright position"); the angle of inclination is between 49 and 56 degrees. The "waist" is smoothed out. The shadow of the heart increases in length but reduces in width.

In individuals of the **brachymorphic type** with a short, broad chest and high diaphragm, the heart seems lifted by the diaphragm and lies on it in a prone, **horizontal position**.

In individuals of the **dolichomorphic type** with a long, narrow chest and low diaphragm, the heart is vertical and hangs as if stretched. In persons whose type is intermediate between the two extreme types of body build, the heart lies **obliquely**. The shape and position of the heart can therefore be judged to a certain measure from the body build and the shape of the chest.

The heart undergoes various **changes with age**. In newborns the cardiovascular shadow occupies an almost median position; the heart is relatively larger than in adults, mainly because of its large right half. The shape of the heart is almost spherical, and the inferior arches are sharply convex; the "waist" is smoothed out. With age the cardiovascular shadow diminishes relatively and moves to the left. In old age the "waist" is outlined more sharply because the aorta is elongated; the heart apex protrudes and is separated from the diaphragmatic cupola. Elongation and deformity of the aorta are characteristic of the heart in old age; the aorta protrudes to the right in the ascending part (forming the convexity of the superior arch on the right contour) and to the left in the region of the arcus (forming the convexity of the superior arch on the left contour).

The sex differences consist in the prevalence of the horizontal position of the heart among females.

The heart “types”, the shape and position of the heart, are not stable even in a single person. For instance, the heart descends during inspiration and increases in length, but is raised by the diaphragm during expiration and increases in width.

A decisive role in the position of the heart is played by the level of the diaphragm; this level changes depending on the respiratory phase, the position of the person examined (the diaphragm is higher in a reclining than in an upright position), body weight (it is higher in fat than in slim patients), body build (it is higher in brachymorphic than in dolichomorphic persons), age (the diaphragm distends with age), and other factors. The variability of these factors results in extreme variability in the shape and position of the heart, To get a correct idea of the normal position, therefore, it is necessary to take in consideration all the possible variants and all the factors responsible for these variants.

The size of the heart depends on the sex, age, body weight and height, structure of the chest, constitution, and conditions of work and everyday life. The absolute dimensions of the heart increase parallel to increase in body weight and height. The development of the musculature has a great effect on the size of the heart, As a result the heart is smaller in females than in males of equal height and body weight. This also explains the dependence of the heart dimensions on an individual's profession. The heart is larger, for instance, in individuals employed in physical labour than in those engaged in sedentary labour. The effect of physical exertion on the heart dimensions is particularly evident from the X-ray examination of athletes. Enlargement of the heart is caused only by those sports in which physical exertion is prolonged, e.g., cycling, rowing, marathon races; the largest hearts are those of skiers. In comparison, enlargement of the heart is relatively less frequent in sprinters, boxers, soccer players, and others.

Angiocardiography involves radiography of the heart and large vessels of a patient after the infusion of the organ and vessels with contrast media. The separate chambers of the heart (the atria and ventricles) and even the heart valves and capillary muscles can be seen with this method. Information of considerable interest is provided by **radiocinematography** of the live heart during circulation. In distinction from examination of a prepared specimen, this method makes it possible to watch the flow of blood from the atria into the ventricles, the routes of blood inflow and outflow from each heart chamber, and the work of the heart valves. Angiocardiography demonstrates the coronary arteries of the heart and their anastomoses (**coronarography**).

THE VESSELS OF PULMONARY (LESSER) CIRCULATION

The arteries of pulmonary circulation

The **pulmonary trunk** (truncus pulmonalis), which carries venous blood from the right ventricle to the lungs, is a continuation of the truncus arteriosus and passes obliquely to the left, crossing the aorta lying behind it. The pulmonary trunk is located in front of the aorta since the pulmonary trunk develops from the ventral part of the truncus arteriosus, whereas the aorta arises from its dorsal part. After a distance of 5-6 cm, the trunk divides under the arch of the aorta on a level with the fourth and fifth thoracic vertebrae into two terminal branches, **the right** and **left pulmonary arteries** (a. pulmonalis dextra and a. pulmonalis sinistra), each passing to the corresponding lung. **The right pulmonary artery**, which is longer, stretches to the right lung behind the ascending aorta and superior vena cava; **the left pulmonary artery** passes in front of the descending aorta. On approaching the lungs, both pulmonary arteries again divide into branches that lead to the corresponding pulmonary lobes, stretch to the bronchi, and branch into minute arteries and capillaries. The pulmonary trunk is covered with a layer of pericardium up to its dividing point. A cord of connective tissue, **lig. arteriosum**, stretches from the site of the division to the concave side of the aorta; this ligament is the obliterated ductus arteriosus (Botalli).

The veins of pulmonary circulation

The pulmonary veins (venae pulmonales) carry arterial blood from the lungs into the left atrium. They arise from the capillaries of the lung and unite into large trunks, **two from each lung** (one **superior** and the other **inferior**) that pass horizontally to the left atrium and drain into its superior wall. Each vein drains through a separate orifice, the right veins at the right and the left veins at the left border of the left atrium. When passing to the left atrium, the right pulmonary veins cross the posterior wall of the right atrium transversely. The pulmonary veins (two on each side) are arranged symmetrically because the trunks that leave the superior and middle lobe of the right lung merge to form a single trunk. The pulmonary veins are not completely isolated from the veins of systemic circulation because they anastomose with the bronchial veins draining into v. azygos. The pulmonary veins have no valves.

The vessels of systemic (greater) circulation

The arteries of systemic circulation

The aorta, the main arterial trunk of systemic circulation, carries blood from the left ventricle of the heart.

The following three sections can be distinguished in the aorta:

1) **aorta ascendens**, the ascending aorta, which develops from the truncus arteriosus;

2) **arcus aortae**, the arch of the aorta, which arises from the fourth left branchial arterial arch; and

3) **aorta descendens**, the descending aorta, which develops from the dorsal arterial trunk of the embryo.

The aorta ascendens begins as a marked bulbous expansion (**bulbus aortae**). Within this distension are **three sinuses of the aorta** (sinus aortae) found between the wall of the aorta and the cusps of its valves. The ascending aorta is approximately 6 cm long. Both the ascending aorta and the pulmonary trunk behind which it is located are still covered at this point with the pericardium. Behind the manubrium of the sternum, the ascending aorta is continuous with **the arcus aortae**, which bends posteriorly and to the left, curves over the left bronchus at its very origin, and is then continuous with the descending aorta on a level with the fourth thoracic vertebra. **The aorta descendens** lies in the posterior mediastinum to the left of the spine. It then deviates slightly to the right so that, in passing through the hiatus aorticus of the diaphragm on the level of the twelfth thoracic vertebra, the aortic trunk is located in front of the spine on the midline. To the level of **the hiatus aorticus**, the descending aorta is called the thoracic aorta (**aorta thoracica**); below the hiatus aorticus, when the aorta is already in the abdominal cavity, it is called the abdominal aorta (**aorta abdominalis**). At the level of fourth lumbar vertebra, it gives off two large terminal branches, the common iliac arteries (bifurcation of aortae), and then continues into the pelvis as a small thin trunk (**a. sacralis mediana**). To stop bleeding in the lower arteries, the abdominal aorta is pressed to the vertebral column in the region of the umbilicus located above the bifurcation (the umbilicus marks the level of the aorta).

The aorta is usually examined **radiologically** together with the heart. In the oblique view (with the left nipple touching the screen), all parts of the aorta are visible: the ascending, the arch, and the descending aorta (to the level of the diaphragm). A clear oval space bounded anteriorly by the shadow of the heart and superiorly and posteriorly by the aorta (retrocardial pulmonary field) is called the "aortic window". This window can be narrow or wide, depending on the shape of the thoracic cage, the level of the diaphragm, and the position of the heart. In patients with a short, broad chest and a high diaphragm, both the ascending and descending parts of the aorta are far from each other. As a result the aortic window is wide, and the arch of the aorta is less curved. The correlation is reversed in patients with a long, narrow chest and a low diaphragm.

Branches of the ascending aorta

The first vessels that arise from the aorta are branches to the heart, **the right** and **left coronary arteries** (aa. coronariae dextra and sinistra).

Branches of the arch of the aorta

The concavity of the aortic border gives off arteries to the bronchi and thymus, whereas the convexity gives rise to **three trunks**, which stretch upward. From right to left, these are: **the truncus brachiocephalicus** (a. anonyma), **a. carotis communis sinistra** and **a. subclavia sinistra**.

The brachiocephalic trunk

The brachiocephalic trunk, innominate artery (truncus brachiocephalicus), about 3-4 cm in length, is a remnant of the embryonic right ventral aorta. It runs obliquely upward, backward, and to the right, anteriorly of the trachea, where it gives off a branch to the thyroid gland, a. thyreoidea ima (**the lowest thyroid artery**), and divides behind the right sternoclavicular joint into its terminal branches, **the right common carotid** and **right subclavian arteries**.

The common carotid artery

The common carotid artery (a. carotis communis) (Gk kayos heavy sleep), develops from the ventral aorta between the third and fourth branchial arteries. It arises from the brachiocephalic trunk on the right and independently from the arch of the aorta on the left side. Both common carotid arteries run upward on the side and between of the trachea and oesophagus. The right common carotid artery consists only of a cervical section and is, thus, shorter than the left, which consists of **a thoracic section** (from the arch of the aorta to the left sternoclavicular joint) and **a cervical section**. The common carotid artery passes in the trigonum caroticum and, at the level of the superior border of the thyroid cartilage or body of the hyoid bone, divides into its **terminal branches**, **the external** and **internal carotid arteries** (a. carotis extern and a. carotis interna) (bifurcation).

To stop bleeding, the common carotid artery is pressed to the tuberculum caroticum of the sixth cervical vertebra at the level of the inferior border of the cricoid cartilage. Sometimes the external and internal carotid arteries arise not from a common trunk but separately from the aorta, which reflects the character of their development. Along its entire length the common carotid artery gives off small branches to the surrounding vessels and nerves (vasa vasorum and vasa nervorum), which may play a role in the development of collateral circulation on the neck.

The external carotid artery

The external carotid artery (a. carotis externs) supplies blood to the external part of the head and neck and is, therefore, distinct from the internal carotid artery penetrating into the cavity of the skull. From its point of origin, the external carotid artery runs upward, passing medial to the posterior belly of the digastric and stylohyoid muscles, pierces the parotid gland, and divides into its terminal branches behind the neck of the mandibular condyloid process.

Most of the branches of the external carotid artery are remnants of the branchial arteries and supply organs derived from the visceral. **Nine** in number, they stretch along the rays of a circle corresponding to the head and may be divided into three groups, called triplets, each containing three arteries - **the anterior, middle,** and **posterior groups**.

The anterior group is conditioned by the development and position of organs supplied by the arteries of this group and derived from the visceral arches, namely, the thyroid gland and larynx (**the superior thyroid artery**), the tongue (**lingual artery**), and the face (**facial artery**).

1. The superior thyroid artery (a. thyreoidea superior) arises from the external carotid artery immediately above its origin and runs downward and anteriorly to the thyroid gland where it anastomoses with the other thyroid arteries (the inferior thyroid artery from a. subclavia and from opposite side). Along the way it gives off branches:

- The **hyoid branch** (ramus hyoideus; infrahyoid branch) is small and runs along the lower border of the hyoid bone beneath the m. Thyreohyoideus and anastomoses with the vessel of the opposite side.
- The **sternocleidomastoid branch** (ramus sternocleidomastoideus) runs downward and lateralward across the sheath of the common carotid artery, and supplies the m. Sternocleidomastoideus and neighboring muscles and integument; it frequently arises as a separate branch from the external carotid.
- The **superior laryngeal artery** (a. laryngea superior), larger than either of the preceding, accompanies the internal laryngeal branch of the superior laryngeal nerve, beneath the m. thyreohyoideus; it pierces the hyothyroid membrane, and supplies the muscles, mucous membrane, and glands of the larynx, anastomosing with the branch from the opposite side.
- The **cricothyroid branch** (ramus cricothyreoideus) is small and runs transversely across the cricothyroid membrane, communicating with the artery of the opposite side.

2. The lingual artery (a. lingualis) arises at the level of the greater horns of the hyoid bone, runs upward through Pirogoff's triangles where it is covered by the hyoglossus muscle, and then passes to the tongue. Before entering the tongue it gives off branches to the hyoid bone **- the hyoid branch** (ramus hyoideus; suprahyoid branch), palatine tonsils, and the sublingual gland **-** t**he sublingual artery** (a. sublingualis). The lingual artery extends to the tip of the tongue, where it is called **the deep lingual artery** (a. profunda linguae; ranine artery), it is the terminal portion of the lingual artery; it pursues a tortuous course and runs along the under surface of the tongue, below the m. longitudinalis inferior, and above the mucous membrane; it lies on the lateral side of the m. genioglossus, accompanied by the lingual nerve. In the mouth, these vessels are placed one on either side of the frenulum linguae.**The** a**rteriae dorsales linguae** (rami dorsales linguae) consist usually of two or three small branches which arise beneath the m.hyoglossus; they ascend to the back part of the dorsum of the tongue, and supply the mucous membrane in this situation, the glossopalatine arch, the tonsil, soft palate, and epiglottis; anastomosing with the vessels of the opposite side.

3. The facial artery (a. facial artery), arises in the carotid triangle a little above the lingual artery and, sheltered by the ramus of the mandible, passes obliquely up beneath the m. digastricus and m. stylohyoideus, over which it arches to enter a groove on the posterior surface of the submandibular gland. It then curves upward over the body of the mandible at the antero-inferior angle of the m. masseter; passes forward and upward across the cheek to the angle of the mouth, then ascends along the side of the nose, and ends at the medial commissure of the eye, under the name of the **angular artery.** This vessel, both in the neck and on the face, is remarkably tortuous: in the former situation, to accommodate itself to the movements of the pharynx in deglutition; and in the latter, to the movements of the mandible, lips, and cheeks.

The branches of the artery may be divided into two sets: those given off in the neck (**cervical**), and those on the face (**facial**).

- The **ascending palatine artery** (a. palatina ascendens) arises close to the origin of the facial artery and passes up between the m. styloglossus and m. stylopharyngeus to the side of the pharynx, along which it is continued between the m. constrictor pharyngis superior and the m. pterygoideus medialis to near the base of the skull. It divides near the m. levator veli palatini into two branches: one follows the course of this muscle, and, winding over the upper border of the m. constrictor pharyngis superior, supplies the soft palate and the palatine glands, anastomosing with its fellow of the opposite side and with the descending palatine branch of the maxillary artery; the other pierces the m. constrictor pharyngis superior and supplies the palatine tonsil and auditory tube, anastomosing with the tonsillar and ascending pharyngeal arteries.
- The **tonsillar branch** (ramus tonsillaris) ascends between the m. pterygoideus medialis and m. styloglossus, and then along the side of the pharynx, perforating the m. constrictor pharyngis superior, to ramify in the substance of the palatine tonsil and root of the tongue.
- The **glandular branches** (rami glandulares; submaxillary branches) consist of three or four large vessels, which supply the submandibular gland, some being prolonged to the neighboring muscles, lymph glands, and skin.
- The **submental artery** (a. submentalis) the largest of the cervical branches, is given off from the facial artery just as that vessel quits the submandibular gland: it runs forward upon the m. mylohyoideus, just below the body of the mandible, and beneath the m. digastricus. It supplies the surrounding muscles, and anastomoses with the sublingual artery and with the mylohyoid branch of the inferior alveolar; at the symphysis menti it turns upward over the border of the mandible and divides into a superficial and a deep branch. **The superficial branch** passes between the integument and m. depresor labii inferioris, and anastomoses with the inferior labial artery; the deep branch runs between the muscle and the bone, supplies the lip, and anastomoses with the inferior labial and mental arteries.
- **The inferior labial artery** (a. labialis inferior; inferior coronary artery) arises near the angle of the mouth; it passes upward and forward beneath the m. triangularis and, penetrating the Orbicularis oris, runs in a tortuous course along the edge of the lower lip between this muscle and the mucous membrane. It supplies the labial glands, the mucous membrane, and the muscles of the lower lip; and anastomoses with the artery of the opposite side, and with the mental branch of the inferior alveolar artery.
- **The superior labial artery** (a. labialis superior; superior coronary artery) is larger and more tortuous than the inferior. It follows a similar course along the edge of the upper lip, lying between the mucous membrane and the m. orbicularis oris, and anastomoses with the artery of the opposite side. It supplies the upper lip, and gives off in its course two or three vessels which ascend to the nose; a **septal branch** ramifies on the nasal septum as far as the point of the nose, and an **alar branch** supplies the ala of the nose.
- **The lateral nasal** branch is derived from the a. facialis as that vessel ascends along the side of the nose. It supplies the ala and dorsum of the nose, anastomosing with its fellow, with the septal and alar branches, with the dorsal nasal branch of the ophthalmic, and with the infraorbital branch of the maxillary.
- **The angular artery** (a. angularis) is the terminal part of the facial artery; it ascends to the medial angle of the orbit, imbedded in the fibers of the angular head of the m. levator labii superioris, and accompanied by the angular vein. On the cheek it distributes branches which anastomose with the infraorbital; after supplying the lacrimal sac and m. orbicularis oculi, it ends by anastomosing with the dorsal nasal branch of the ophthalmic artery.
- **The muscular branches** in the neck are distributed to the m. pterygoideus medialis and m. stylohyoideus, and on the face to the m. masseter and m. buccinator. The anastomoses of the facial artery are very numerous, not only with the vessel of the opposite side, but, in the neck, with the sublingual branch of the

lingual, with the ascending pharyngeal, and by its ascending palatine and tonsillar branches with the palatine branch of the maxillary; on the face, with the mental branch of the inferior alveolar as it emerges from the mental foramen, with the transverse facial branch of the superficial temporal, with the infraorbital branch of the maxillary, and with the dorsal nasal branch of the ophthalmic.

The facial artery not infrequently arises in common with the lingual artery. It varies in its size and in the extent to which it supplies the face; it occasionally ends as the submental, and not infrequently extends only as high as the angle of the mouth or nose. The deficiency is then compensated for by enlargement of one of the neighboring arteries.

4. The occipital artery (a. occipitalis) arises from the posterior part of the external carotid, opposite the facial artery, near the lower margin of the posterior belly of the m. digastricus, and ends in the posterior part of the scalp. At its origin, it is covered by the posterior belly of the m. digastricus and the m. stylohyoideus, and the hypoglossal nerve winds around it from behind forward; higher up, it crosses the internal carotid artery, the internal jugular vein, and the vagus and accessory nerves. It next ascends to the interval between the transverse process of the atlas and the mastoid process of the temporal bone, and passes horizontally backward, grooving the surface of the latter bone, being covered by the m. sternocleidomastoideus, m. splenius capitis, m. longissimus capitis, and m. digastricus, and resting upon the m. rectus capitis lateralis, the m. obliquus superior, and m. semispinalis capitis. It then changes its course and runs vertically upward, pierces the fascia connecting the cranial attachment of the m. trapezius with the m. sternocleidomastoideus, and ascends in a tortuous course in the superficial fascia of the scalp, where it divides into numerous branches, which reach as high as the vertex of the skull and anastomose with the posterior auricular and superficial temporal arteries. Its terminal portion is accompanied by the greater occipital nerve.

The branches of occipital artery are:

- **The muscular branches** (rami musculares) supply the m. digastricus, m. stylohyoideus, m. splenius, and m. longissimus capitis.
- **The sternocleidomastoid artery** (a. sternocleidomastoidea; sternomastoid artery) generally arises from the occipital close to its commencement, but sometimes springs directly from the external carotid. It passes downward and backward over the hypoglossal nerve, and enters the substance of the muscle, in company with the accessory nerve.
- **The auricular branch** (ramus auricularis) supplies the back of the concha and frequently gives off a branch, which enters the skull through the mastoid foramen and supplies the dura mater, the diploë, and the mastoid cells; this latter branch sometimes arises from the occipital artery, and is then known as the **mastoid branch.**
- **The meningeal branch** (ramus meningeus; dural branch) ascends with the internal jugular vein, and enters the skull through the jugular foramen and condyloid canal, to supply the dura mater in the posterior fossa.
- **The descending branch** (ramus descendens; arteria princeps cervicis), the largest branch of the occipital, descends on the back of the neck, and divides into **a superficial** and **deep portion**. The superficial portion runs beneath the m. splenius, giving off branches which pierce that muscle to supply the m. trapezius and anastomose with the ascending branch of the transverse cervical artery: the deep portion runs down between the m. semispinales capitis and colli, and anastomoses with the vertebral and with the a. profunda cervicalis (costocervical trunk). The anastomosis between these vessels assists in establishing the collateral circulation after ligature of the common carotid or subclavian artery.

The terminal branches of the occipital artery are distributed to the back of the head: they are very tortuous, and lie between the integument and m. occipitalis, anastomosing with the artery of the opposite side and with the posterior auricular and temporal arteries, and supplying the m. occipitalis, the integument, and pericranium. One of the terminal branches may give off a meningeal twig which passes through the parietal foramen.

5. The posterior auricular artery (a. auricularis posterior) is small and arises from the external carotid, above the m. digastricus and m. stylohyoideus, opposite the apex of the styloid process. It ascends, under cover of the parotid gland, on the styloid process of the temporal bone, to the groove between the cartilage of the ear and the mastoid process, immediately above which it divides into its auricular and occipital branches. Besides several small branches to the m. digastricus, m. stylohyoideus, and m. sternocleidomastoideus, and to the parotid gland, this vessel gives off three branches:

- **The stylomastoid artery** (a. stylomastoidea) enters the stylomastoid foramen and supplies the tympanic cavity, the tympanic antrum and mastoid cells, and the semicircular canals. In the young subject a branch from this vessel forms, with the anterior tympanic artery from the maxillary, a vascular circle, which surrounds the tympanic membrane, and from which delicate vessels ramify on that membrane. It anastomoses with the superficial petrosal branch of the middle meningeal artery by a twig which enters the hiatus canalis facialis.
- **The auricular branch** (ramus auricularis) ascends behind the ear, beneath the m. auricularis posterior, and is distributed to the back of the auricula, upon which it ramifies minutely, some branches curving around the margin of the cartilage, others perforating it, to supply the anterior surface. It anastomoses with the parietal and anterior auricular branches of the superficial temporal.
- **The occipital branch** (ramus occipitalis) passes backward, over the m. sternocleidomastoideus, to the scalp above and behind the ear. It supplies the m. occipitalis and the scalp in this situation and anastomoses with the occipital artery.

6. The ascending pharyngeal artery (a. pharyngea ascendens), the smallest branch of the external carotid, is a long, slender vessel, deeply seated in the neck, beneath the other branches of the external carotid and under the m. stylopharyngeus. It arises from the back part of the external carotid, near the starting of that vessel, and ascends vertically between the internal carotid and the side of the pharynx, to the under surface of the base of the skull, lying on the m. longus capitis. Its branches are:

- **The pharyngeal branches** (rami pharyngei) are three or four in number. Two of these descend to supply the m. constrictores pharyngis medius and inferior and the m. stylopharyngeus, ramifying in their substance and in the mucous membrane lining them.
- **The palatine branch** varies in size, and may take the place of the ascending palatine branch of the facial artery, when that vessel is small. It passes inward upon the m. constrictor pharyngis superior, sends ramifications to the soft palate and tonsil, and supplies a branch to the auditory tube.
- **The prevertebral branches** are numerous small vessels, which supply the Longi capitis and colli, the sympathetic trunk, the hypoglossal and vagus nerves, and the lymph glands; they anastomose with the ascending cervical artery.
- **The inferior tympanic artery** (a. tympanica inferior) is a small branch which passes through a minute foramen in the petrous portion of the temporal bone, in company with the tympanic branch of the glossopharyngeal nerve, to supply the medial wall of the tympanic cavity and anastomose with the other tympanic arteries.
- **The meningeal branches** are several small vessels, which supply the dura mater. One, the posterior meningeal, enters the cranium through the jugular foramen; a second passes through the foramen lacerum; and occasionally a third through the canal for the hypoglossal nerve.

7. The superficial temporal artery (a. temporalis superficialis), the smaller of the two terminal branches of the external carotid, appears, from its direction, to be the continuation of that vessel. It begins in the substance of the parotid gland, behind the neck of the mandible, and corsses over the posterior root of the zygomatic process of the temporal bone; about 5 cm. above this process it bifurcates into two, a frontal and a parietal branches. As it crosses the zygomatic process, it is covered by the m. auricularis anterior muscle, and by a dense fascia; it is crossed by the temporal and zygomatic branches of the facial nerve and one or two veins, and is accompanied by the auriculotemporal nerve, which lies immediately behind it. Besides some twigs to the parotid gland, to the temporomandibular joint, and to the m. masseter muscle, its branches are:

- The **transverse facial artery** (a. transversa faciei) is givien off from the superficial temporal before that vessel quits the parotid gland; running forward through the substance of the gland, it passes transversely across the side of the face, between the parotid duct and the lower border of the zygomatic arch, and divides into numerous branches, which supply the parotid gland and duct, the m. masseter, and the skin, and anastomose with the facial, masseteric, buccinator, and infraorbital arteries. This vessel rests on the m. masseter, and is accompanied by one or two branches of the facial nerve.
- **The middle temporal artery** (a. temporalis media) arises immediately above the zygomatic arch, and, perforating the temporal fascia, gives branches to the m. temporalis, anastomosing with the deep temporal branches of the maxillary. It occasionally gives off a **zygomatico-orbital branch,** which runs along the

upper border of the zygomatic arch, between the two layers of the temporal fascia, to the lateral angle of the orbit. This branch, which may arise directly from the superficial temporal artery, supplies the m. orbicularis oculi, and anastomoses with the lacrimal and palpebral branches of the ophthalmic artery.

- **The anterior auricular branches** (rami auriculares anteriores) are distributed to the anterior portion of the auricula, the lobule, and part of the external meatus, anastomosing with the posterior auricular.
- **The frontal branch** (ramus frontalis; anterior temporal) runs tortuously upward and forward to the forehead, supplying the muscles, integument, and pericranium in this region, and anastomosing with the supraorbital and frontal arteries.
- **The parietal branch** (ramus parietalis; posterior temporal) larger than the frontal, curves upward and backward on the side of the head, lying superficial to the temporal fascia, and anastomosing with its fellow of the opposite side, and with the posterior auricular and occipital arteries.

8. The maxillary artery (a. maxillaris), the larger of the two terminal branches of the external carotid, arises behind the neck of the mandible, and is at first imbedded in the substance of the parotid gland; it passes forward between the ramus of the mandible and the sphenomandibular ligament, and then runs, either superficial or deep to the m. pterygoideus lateralis, to the pterygopalatine fossa. It supplies the deep structures of the face, and may be divided into 3 portions**: mandibular, pterygoid,** and **pterygopalatine.**

The **first** or **mandibular portion** passes horizontally forward, between the ramus of the mandible and the sphenomandibular ligament, where it lies parallel to and a little below the auriculotemporal nerve; it crosses the inferior alveolar nerve, and runs along the lower border of the m. pterygoideus lateralis. Branches of the this portions are:

- **The anterior tympanic artery** (a. tympanica anterior; tympanic artery) passes upward behind the temporomandibular articulation, enters the tympanic cavity through the petrotympanic fissure, and ramifies upon the tympanic membrane, forming a vascular circle around the membrane with the stylomastoid branch of the posterior auricular, and anastomosing with the artery of the pterygoid canal and with the caroticotympanic branch from the internal carotid.
- **The deep auricular artery** (a. auricularis profunda) often arises in common with the preceding. It ascends in the substance of the parotid gland, behind the temporomandibular articulation, pierces the cartilaginous or bony wall of the external acoustic meatus, and supplies its cuticular lining and the outer surface of the tympanic membrane. It gives a branch to the temporomandibular joint.
- **The middle meningeal artery** (a. meningea media) is the largest of the arteries which supply the dura mater. It ascends between the sphenomandibular ligament and the m. pterygoideus lateralis, and between the two roots of the auriculotemporal nerve to the foramen spinosum of the sphenoid bone, through which it enters the cranium; it then runs forward in a groove on the great wing of the sphenoid bone, and divides into two branches, anterior and posterior. The **anterior branch,** the larger, crosses the great wing of the sphenoid, reaches the groove, or canal, in the sphenoidal angle of the parietal bone, and then divides into branches which spread out between the dura mater and internal surface of the cranium, some passing upward as far as the vertex, and others backward to the occipital region. The **posterior branch** curves backward on the squama of the temporal bone, and, reaching the parietal some distance in front of its mastoid angle, divides into branches which supply the posterior part of the dura mater and cranium. The branches of the middle meningeal artery are distributed partly to the dura mater, but chiefly to the bones; they anastomose with the arteries of the opposite side, and with the anterior and posterior meningeal. The middle meningeal anatomy on entering the cranium gives off the following branches:

  1) Numerous small vessels supply the semilunar ganglion and the dura mater in this situation.

  2) A **superficial petrosal** branch enters the hiatus of the facial canal, supplies the facial nerve, and anastomoses with the stylomastoid branch of the posterior auricular artery.

  3) A **superior tympanic artery** runs in the canal for the m. tensor tympani, and supplies this muscle and the lining membrane of the canal.

  4) **orbital branches** pass through the superior orbital fissure or through separate canals in the great wing of the sphenoid, to anastomose with the lacrimal or other branches of the ophthalmic artery.

  5) **temporal branches** pass through foramina in the great wing of the sphenoid, and anastomose in the temporal fossa with the deep temporal arteries.

- The a**ccessory meningeal branch** (ramus meningeus accessorius) is sometimes derived from the preceding. It enters the skull through the foramen ovale, and supplies the semilunar ganglion and dura mater.
- The i**nferior alveolar artery** (a. alveolaris inferior; inferior dental artery) descends with the inferior alveolar nerve to the mandibular foramen on the medial surface of the ramus of the mandible. It runs along the mandibular canal in the substance of the bone, accompanied by the nerve, and opposite the first premolar tooth divides into two branches, incisor and mental. The **incisor branch** is continued forward beneath the incisor teeth as far as the middle line, where it anastomoses with the artery of the opposite side; the **mental branch** escapes with the nerve at the mental foramen, supplies the chin, and anastomoses with the submental and inferior labial arteries. Near its origin the inferior alveolar artery gives off a **lingual branch** which descends with the lingual nerve and supplies the mucous membrane of the mouth. As the inferior alveolar artery enters the foramen, it gives off a **mylohyoid branch** which runs in the mylohyoid groove, and ramifies on the under surface of the m. mylohyoideus. The inferior alveolar artery and its incisor branch during their course through the substance of the bone give off a few twigs which are lost in the cancellous tissue, and a series of branches which correspond in number to the roots of the teeth: these enter the minute apertures at the extremities of the roots, and supply the pulp of the teeth.

The **second** or **pterygoid portion** runs obliquely forward and upward under cover of the ramus of the mandible and insertion of the m. temporalis, on the superficial (very frequently on the deep) surface of the m. pterygoideus lateralis; it then passes between the two heads of origin of this muscle and enters the fossa. Branches of the pterygoid portion are.

- The **deep temporal branches,** two in number, **anterior** and **posterior,** ascend between the m. temporalis and the pericranium; they supply the muscle, and anastomose with the middle temporal artery; the anterior communicates with the lacrimal artery by means of small branches which perforate the zygomatic bone and great wing of the sphenoid.
- The **pterygoid branches** (rami pterygoidei), irregular in their number and origin, supply the pterygoidei muscles.
- The **masseteric artery** (a. masseterica) is small and passes lateralward through the mandibular notch to the deep surface of the m. masseter. It supplies the muscle, and anastomoses with the masseteric branches of the facial artery and with the transverse facial artery.
- The **buccinator artery** (a. buccinatoria) is small and runs obliquely forward, between the Pterygoideus medialis and the insertion of the m. temporalis, to the outer surface of the m. buccinator, to which it is distributed, anastomosing with branches of the facial and with the infraorbital arteries.

The **third** or **pterygopalatine portion** lies in the pterygopalatine fossa in relation with the sphenopalatine ganglion. Branches of the pterygopalatine portion are:

- **The posterior superior alveolar artery** (a. alveolaris superior posterior) is given off from the maxillary, frequently in conjunction with the infraorbital just as the trunk of the vessel is passing into the pterygopalatine fossa. Descending upon the tuberosity of the maxilla, it divides into numerous branches, some of which enter the alveolar canals, to supply the molar and premolar teeth and the lining of the maxillary sinus, while others are continued forward on the alveolar process to supply the gums.
- **The infraorbital artery** (a. infraorbitalis) appears, from its direction, to be the continuation of the trunk of the maxillary, but often arises in conjunction with the posterior superior alveolar. It runs along the infraorbital groove and canal with the infraorbital nerve, and emerges on the face through the infraorbital foramen, beneath the infraorbital head of the m. levator labii superioris. While in the canal, it gives off:

  a) **orbital branches** which assist in supplying the m. rectus inferior and m. obliquus inferior and the lacrimal sac, and

  b) **anterior superior alveolar branches** which descend through the anterior alveolar canals to supply the upper incisor and canine teeth and the mucous membrane of the maxillary sinus.

  On the face, some branches pass upward to the medial angle of the orbit and the lacrimal sac, anastomosing with the angular branch of the facial artery; others run toward the nose, anastomosing with the dorsal nasal branch of the ophthalmic; and others descend between the m. levator labii superioris and the caninus, and anastomose with the facial, transverse facial, and buccinator arteries.

The four remaining branches arise from that portion of the maxillary which is contained in the pterygopalatine fossa.

- **The descending palatine artery** (a. palatina descendens) descends through the pterygopalatine canal with the anterior palatine branch of the sphenopalatine ganglion, and, emerging from the greater palatine foramen, runs forward in a groove on the medial side of the alveolar border of the hard palate to the incisive canal; the terminal branch of the artery passes upward through this canal to anastomose with the sphenopalatine artery. Branches are distributed to the gums, the palatine glands, and the mucous membrane of the roof of the mouth; while in the pterygopalatine canal it gives off twigs which descend in the lesser palatine canals to supply the soft palate and palatine tonsil, anastomosing with the ascending palatine artery (a. facialis).
- **The artery of the pterygoid canal** (a. canalis pterygoidei; Vidian artery) passes backward along the pterygoid canal with the corresponding nerve. It is distributed to the upper part of the pharynx and to the auditory tube, sending into the tympanic cavity a small branch which anastomoses with the other tympanic arteries.
- **The pharyngeal branch** is very small; it runs backward through the pharyngeal canal with the pharyngeal nerve, and is distributed to the upper part of the pharynx and to the auditory tube.
- **The sphenopalatine artery** (a. sphenopalatina) passes through the sphenopalatine foramen into the cavity of the nose, at the back part of the superior meatus. Here it gives off its **posterior lateral nasal branches** which spread forward over the conchae and meatuses, anastomose with the ethmoidal arteries and the nasal branches of the descending palatine, and assist in supplying the frontal, maxillary, ethmoidal, and sphenoidal sinuses. Crossing the under surface of the sphenoid the sphenopalatine artery ends on the nasal septum as the **posterior septal branches;** these anastomose with the ethmoidal arteries and the septal branch of the superior labial; one branch descends in a groove on the vomer to the incisive canal and anastomoses with the descending palatine artery.

The internal carotid artery

The internal carotid artery supplies the anterior part of the brain, the eye and its appendages, and sends branches to the forehead and nose. Its size, in the adult, is equal to that of the external carotid, though, in the child, it is larger than that vessel. It is remarkable for the number of curvatures that it presents in different parts of its course. It occasionally has one or two flexures near the base of the skull, while in its passage through the carotid canal and along the side of the body of the sphenoid bone it describes a double curvature and resembles the letter S. In considering the course and relations of this vessel it may be divided into four portions: **cervical, petrous, cavernous,** and **cerebral.**

Cervical portion.

This portion of the internal carotid begins at the bifurcation of the common carotid, opposite the upper border of the thyroid cartilage, and runs perpendicularly upward, in front of the transverse processes of the upper three cervical vertebrae, to the carotid canal in the petrous portion of the temporal bone. It is comparatively superficial at its start, where it is contained in the carotid triangle, and lies behind and lateral to the external carotid, overlapped by the m. sternocleidomastoideus, and covered by the deep fascia, m. platysma, and integument: it then passes beneath the parotid gland, being crossed by the hypoglossal nerve, the m. digastricus and m. stylohyoideus, and the occipital and posterior auricular arteries. Higher up, it is separated from the external carotid by the m. styloglossus and m. stylopharyngeus, the tip of the styloid process and the stylohyoid ligament, the glossopharyngeal nerve and the pharyngeal branch of the vagus. It is in relation, behind, with the m. longus capitis, the superior cervical ganglion of the sympathetic trunk, and the superior laryngeal nerve; laterally, with the internal jugular vein and vagus nerve, the nerve lying on a plane posterior to the artery; medially, with the pharynx, superior laryngeal nerve, and ascending pharyngeal artery. At the base of the skull the glossopharyngeal, vagus, accessory, and hypoglossal nerves lie between the artery and the internal jugular vein.

Petrous Portion.

When the internal carotid artery enters the canal in the petrous portion of the temporal bone, it first ascends a short distance, then curves forward and medialward, and again ascends as it leaves the canal to enter the cavity of the skull between the lingula and petrosal process of the sphenoid. The artery lies at first in front of the cochlea and tympanic cavity; from the latter cavity it is separated by a thin, bony lamella, which is cribriform in the young subject, and often partly absorbed in old age. Farther forward it is separated from the semilunar ganglion by a thin plate of bone, which forms the floor of the fossa for the ganglion and the roof of the horizontal portion of the canal. Frequently this bony plate is more or less deficient, and then the ganglion is separated from the artery by fibrous membrane. The artery is separated from the bony wall of the carotid canal by a prolongation of dura mater, and is surrounded by a number of small veins and by filaments of the carotid plexus, derived from the ascending branch of the superior cervical ganglion of the sympathetic trunk.

Cavernous portion.

In this part of its course, the artery is situated between the layers of the dura mater forming the cavernous sinus, but covered by the lining membrane of the sinus. It at first ascends toward the posterior clinoid process, then passes forward by the side of the body of the sphenoid bone, and again curves upward on the medial side of the anterior clinoid process, and perforates the dura mater forming the roof of the sinus. This portion of the artery is surrounded by filaments of the sympathetic nerve, and on its lateral side is the abducent nerve.

Cerebral portion.

Having perforated the dura mater on the medial side of the anterior clinoid process, the internal carotid passes between the optic and oculomotor nerves to the anterior perforated substance at the medial extremity of the lateral cerebral fissure, where it gives off its terminal or cerebral branches.

The length of the internal carotid variates according to the length of the neck, and also according to the point of bifurcation of the common carotid. It arises sometimes from the arch of the aorta; in such rare instances, this vessel has been found to be placed nearer the middle line of the neck than the external carotid, as far upward as the larynx, when the latter vessel crossed the internal carotid. The course of the artery, instead of being straight, may be very tortuous. A few instances are recorded in which this vessel was altogether absent; in one of these the common carotid passed up the neck, and gave off the usual branches of the external carotid; the cranial portion of the internal carotid was replaced by two branches of the maxillary, which entered the skull through the foramen rotundum and foramen ovale, and joined to form a single vessel.

The cervical portion of the internal carotid gives off no branches. From the other portions there are:

Petrous Portion	**Cavernous Portion**	**Cerebral Portion**
Caroticotympanic	Cavernous	Anterior Cerebral
Artery of the Pterygoid Canal	Hypophyseal	Middle Cerebral
	Semilunar	Posterior Communicating
	Anterior Meningeal	Anterior Choroidal
	Ophthalmic	

1. The caroticotympanic branch (ramus caroticotympanicus) is small; it enters the tympanic cavity through a minute foramen in the carotid canal, and anastomoses with the anterior tympanic branch of the maxillary, and with the stylomastoid artery.

2. The artery of the pterygoid canal (a. canilis pterygoidei [Vidii]) is a small, inconstant branch which passes into the pterygoid canal and anastomoses with a branch of the maxillary artery.

3. The cavernous branches are numerous small vessels which supply the hypophysis, the semilunar ganglion, and the walls of the cavernous and inferior petrosal sinuses. Some of them anastomose with branches of the middle meningeal.

4. The hypophyseal branches are one or two minute vessels supplying the hypophysis.

5. The semilunar branches are small vessels to the semilunar ganglion.

6. The anterior meningeal branch (a. meningea anterior) is a small branch which passes over the small wing of the sphenoid to supply the dura mater of the anterior cranial fossa; it anastomoses with the meningeal branch from the posterior ethmoidal artery.

7. The ophthalmic artery (a. ophthalmica) arises from the internal carotid, just as that vessel is emerging from the cavernous sinus, on the medial side of the anterior clinoid process, and enters the orbital cavity through the optic foramen, below and lateral to the optic nerve. It then passes over the nerve to reach the medial wall of the orbit, and thence horizontally forward, beneath the lower border of the m. obliquus superior, and divides it into two terminal branches, the **frontal** and **dorsal nasal arteries.** As the artery crosses the optic nerve it is accompanied by the nasociliary nerve, and is separated from the frontal nerve by the m. rectus superior and m. levator palpebrae superioris.

The branches of the ophthalmic artery may be divided into an **orbital group,** distributed to the orbit and surrounding parts; and an **ocular group,** to the muscles and bulb of the eye.

- **The lacrimal artery** (a. lacrimalis) arises close to the optic foramen, and is one of the largest branches derived from the ophthalmic: not infrequently it is given off before the artery enters the orbit. It accompanies the lacrimal nerve along the upper border of the m. rectus lateralis, and supplies the lacrimal gland. Its terminal branches, escaping from the gland, are distributed to the eyelids and conjunctiva: of those supplying the eyelids, two are of considerable size and are named the **lateral palpebral arteries;** they run medialward in the **upper** and **lower** lids respectively and anastomose with the medial palpebral arteries, forming an arterial circle in this situation. The lacrimal artery give off one or two **zygomatic branches,** one of which passes through the zygomatico-temporal foramen, to reach the temporal fossa, and anastomoses with the deep temporal arteries; another appears on the cheek through the zygomatico-facial foramen, and anastomoses with the transverse facial. A **recurrent branch** passes backward through the lateral part of the superior orbital fissure to the dura mater, and anastomoses with a branch of the middle meningeal artery. The lacrimal artery is sometimes derived from one of the anterior branches of the middle meningeal artery.
- **The supraorbital artery** (a. supraorbitalis) springs from the ophthalmic as that vessel is crossing over the optic nerve. It passes upward on the medial borders of the m. trectus superior and m. levator palpebrae, and meeting the supraorbital nerve accompanies it between the periosteum and m. levator palpebrae to the supraorbital foramen; passing through this it divides into a superficial and a deep branch, which supply the integument, the muscles, and the pericranium of the forehead, anastomosing with the frontal, the frontal branch of the superficial temporal, and the artery of the opposite side. This artery in the orbit supplies the m. rectus superior and the m. levator palpebrae, and sends a branch across the pulley of the m. obliquus superior, to supply the parts at the medial palpebral commissure. At the supraorbital foramen it frequently transmits a branch to the diploë.
- **The ethmoidal arteries** are two in number: **posterior** and **anterior. The posterior ethmoidal artery,** the smaller, passes through the posterior ethmoidal canal, supplies the posterior ethmoidal cells, and, entering the cranium, gives off a meningeal branch to the dura mater, and nasal branches which descend into the nasal cavity through apertures in the cribriform plate, anastomosing with branches of the sphenopalatine. **The anterior ethmoidal artery** accompanies the nasociliary nerve through the anterior ethmoidal canal, supplies the anterior and middle ethmoidal cells and frontal sinus, and, entering the cranium, gives off a meningeal branch to the dura mater, and nasal branches; these latter descend into the nasal cavity through the slit by the side of the crista galli, and, running along the groove on the inner surface of the nasal bone, supply branches to the lateral wall and septum of the nose, and a terminal branch which appears on the dorsum of the nose between the nasal bone and the lateral cartilage.
- **The medial palpebral arteries** (aa. palpebrales mediales; internal palpebral arteries), two in number, **superior** and **inferior,** arise from the ophthalmic, opposite the pulley of the m. obliquus superior; they leave the orbit to encircle the eyelids near their free margins, forming **a superior** and **an inferior palpebral arches**, which lie between the m. orbicularis oculi and the tarsi. The **superior palpebral** anastomoses, at the lateral angle of the orbit, with the zygomatico-orbital branch of the temporal artery and with the upper of the two lateral palpebral branches from the lacrimal artery; the **inferior palpebral** anastomoses, at the lateral angle of the orbit, with the lower of the two lateral palpebral branches from the lacrimal and with the transverse facial artery, and, at the medial part of the lid, with a branch from the angular artery. From this last anastomoses a branch passes to the nasolacrimal duct, ramifying in its mucous membrane, as far as the inferior meatus of the nasal cavity.
- **The frontal artery** (a. frontalis), one of the terminal branches of the ophthalmic, leaves the orbit at its medial angle with the supratrochlear nerve, and, ascending on the forehead, supplies the integument, muscles, and pericranium, anastomosing with the supraorbital artery, and with the artery of the opposite side.

- **The dorsal nasal artery** (a. dorsalis nasi), the other terminal branch of the ophthalmic, emerges from the orbit above the medial palpebral ligament, and, after giving a twig to the upper part of the lacrimal sac, divides into two branches, one of which crosses the root of the nose, and anastomoses with the angular artery, the other runs along the dorsum of the nose, supplies its outer surface; and anastomoses with the artery of the opposite side, and with the lateral nasal branch of the a.facialis.
- **The central artery of the retina** (a. centralis retinae) is the first and one of the smallest branches of the ophthalmic artery. It runs for a short distance within the dural sheath of the optic nerve, but about 1,25 cm. behind the eyeball it pierces the nerve obliquely, and runs forward in the center of its substance to the retina.
- **The ciliary arteries** (aa. ciliares) are divisible into three groups, the long and short, posterior, and the anterior. The **short posterior ciliary arteries** from six to twelve in number, arise from the ophthalmic, or its branches; they pass forward around the optic nerve to the posterior part of the eyeball, pierce the sclera around the entrance of the nerve, and supply the choroid and ciliary processes. The **long posterior ciliary arteries,** two in number, pierce the posterior part of the sclera at some little distance from the optic nerve, and run forward, along either side of the eyeball, between the sclera and choroid, to the ciliary muscle, where they divide into two branches; these form an arterial circle, the **circulus arteriosus major,** around the circumference of the iris, from which numerous converging branches run, in the substance of the iris, to its pupillary margin, where they form a second arterial circle, the **circulus arteriosus minor.** The **anterior ciliary arteries** are derived from the muscular branches; they run to the front of the eyeball in company with the tendons of the Recti, form a vascular zone beneath the conjunctiva, and then pierce the sclera a short distance from the cornea and end in the circulus arteriosus major.
- The m**uscular branches,** (rami musculares), two in number, **superior and inferior,** frequently spring from a common trunk. The **superior,** often wanting, supplies the m. levator palpebrae superioris, m. rectus superior, and m. obliquus superior. The **inferior,** more constantly present, passes forward between the optic nerve and m. rectus inferior, and is distributed to the m. recti lateralis, medialis, and inferior, and the m. obliquus inferior. This vessel gives off most of the anterior ciliary arteries. Additional muscular branches are given off from the lacrimal and supraorbital arteries, or from the trunk of the ophthalmic.

8. The anterior cerebral artery (a. cerebri anterior) arises from the internal carotid, at the medial extremity of the lateral cerebral fissure. It passes forward and medialward across the anterior perforated substance, above the optic nerve, to the commencement of the longitudinal fissure. Here it comes into close relationship with the opposite artery, to which it is connected by a short trunk, the **anterior communicating artery.** From this point the two vessels run side by side in the longitudinal fissure, curve around the genu of the corpus callosum, and turning backward continue along the upper surface of the corpus callosum to its posterior part, where they end by anastomosing with the posterior cerebral arteries. In its course the anterior cerebral artery gives off the following branches:

- **The antero-medial ganglionic (nuclear) branches** are a group of small arteries which arise at the commencement of the anterior cerebral artery; they pierce the anterior perforated substance and lamina terminalis, and supply the rostrum of the corpus callosum, the septum pellucidum, and the head of the caudate nucleus. The **inferior branches,** two or three in number, are distributed to the orbital surface of the frontal lobe, where they supply the olfactory lobe, gyrus rectus, and internal orbital gyrus. The **anterior branches** supply a part of the superior frontal gyrus, and send twigs over the edge of the hemisphere to the superior and middle frontal gyri and upper part of the anterior central gyrus. The **middle branches** supply the corpus callosum, the cingulate gyrus, the medial surface of the superior frontal gyrus, and the upper part of the anterior central gyrus. The **posterior branches** supply the precuneus and adjacent lateral surface of the hemisphere.
- **The anterior communicating artery** (a. communicans anterior) connects the two anterior cerebral arteries across the commencement of the longitudinal fissure. Sometimes this vessel is wanting, the two arteries joining together to form a single trunk, which afterward divides; or it may be wholly, or partially, divided into two. Its length averages about 4 mm., but varies greatly. It gives off some of the antero-medial ganglionic vessels, but these are principally derived from the anterior cerebral.

9. The middle cerebral artery (a. cerebri media), the largest branch of the internal carotid, runs at first lateralward in the lateral cerebral or Sylvian fissure and then backward and upward on the surface of the insula, where it divides into a number of branches which are distributed to the lateral surface of the cerebral hemisphere. The branches of this vessel are the:

- The **antero-lateral ganglionic (nuclear) branches,** a group of small arteries which arise at the commencement of the middle cerebral artery, are arranged in two sets: one, the **internal striate,** passes upward through the inner segments of the lentiform nucleus, and supplies it, the caudate nucleus, and the internal capsule; the other, the **external striate,** ascends through the outer segment of the lentiform nucleus, and supplies the caudate nucleus and the thalamus. One artery of this group is of larger size than the rest, and is of special importance, as being the artery in the brain most frequently ruptured; it has been termed by Charcot the **artery of cerebral hemorrhage.** It ascends between the lentiform nucleus and the external capsule, and ends in the caudate nucleus. The **inferior lateral frontal** supplies the inferior frontal gyrus (Broca's gyrus) and the lateral part of the orbital surface of the frontal lobe. The **ascending frontal** supplies the anterior central gyrus. The **ascending parietal** is distributed to the posterior central gyrus and the lower part of the superior parietal lobule. The **parietotemporal** supplies the supramarginal and angular gyri, and the posterior parts of the superior and middle temporal gyri. The **temporal branches,** two or three in number, are distributed to the lateral surface of the temporal lobe.

10. The posterior communicating artery (a. communicans posterior) runs backward from the internal carotid, and anastomoses with the posterior cerebral, a branch of the basilar. It varies in size, being sometimes small, and occasionally so large that the posterior cerebral may be considered as arising from the internal carotid rather than from the basilar. It is frequently larger on one side than on the other. From its posterior half are given off a number of small branches, the **postero-medial ganglionic (nuclear) branches,** which, with similar vessels from the posterior cerebral, pierce the posterior perforated substance and supply the medial surface of the thalami and the walls of the third ventricle.

11. The anterior choroidal (a. chorioidea) is a small but constant branch, which arises from the internal carotid, near the posterior communicating artery. Passing backward and lateralward between the temporal lobe and the cerebral peduncle, it enters the inferior horn of the lateral ventricle through the choroidal fissure and ends in the choroid plexus. It is distributed to the hippocampus, fimbria, tela chorioidea of the third ventricle, and choroid plexus.

Since the mode of distribution of the vessels of the brain has an important bearing upon a considerable number of the pathological lesions which may occur in this part of the nervous system, it is important to consider a little more in detail the manner in which the vessels are distributed.

The cerebral arteries are derived from the internal carotid and vertebral, which at the base of the brain form a remarkable anastomosis known as the **arterial circle of Willis.** It is formed in front by the anterior cerebral arteries, branches of the internal carotid, which are connected together by the anterior communicating; behind by the two posterior cerebral arteries, branches of the basilar, which are connected on either side with the internal carotid by the posterior communicating. The parts of the brain included within this arterial circle are the lamina terminalis, the optic chiasma, the infundibulum, the tuber cinereum, the corpora mammillaria, and the posterior perforated substance.

The cortical arterial system.

The vessels forming this system are the terminal branches of the anterior, middle, and posterior cerebral arteries. They divide and ramify in the substance of the pia mater, and give off branches which penetrate the brain cortex, perpendicularly. These branches are divisible into two classes, long and short. The **long,** or **medullary arteries,** pass through the gray substance and penetrate the subjacent white substance to the depth of 3 or 4 cm., without intercommunicating otherwise than by very fine capillaries, and thus constitute so many independent small systems. The **short vessels** are confined to **the cortex**, where they form with the long vessels a compact net-work in the middle zone of the gray substance, the outer and inner zones being sparingly supplied with blood. The vessels of the cortical arterial system are not so strictly "terminal" as those of the ganglionic system, but they approach this type very closely, so that injection of one area from the vessel of another area, though possible, is frequently very difficult, and is only effected through vessels of small caliber. As a result of this, obstruction of one of the main branches, or its divisions, may have the effect of producing softening in a limited area of the cortex.

The subclavian artery

The subclavian artery (a. subclavia). On the right side the **subclavian artery** arises from the innominate artery behind the right sternoclavicular articulation; on the left side it springs from the arch of the aorta. The two vessels, therefore, in the first part of their course, differ in length, direction, and relation with neighboring structures.

In order to facilitate the description, each subclavian artery is divided into **three parts**. **The first portion** extends from the origin of the vessel to the medial border of the m. scalenus anterior; **the second** lies behind this muscle; and **the third** extends from the lateral margin of the muscle to the outer border of the first rib, where it becomes the axillary artery. The first portions of the two vessels require separate descriptions; the second and third parts of the two arteries are practically similar.

First part of the right subclavian artery arises from the innominate artery, behind the upper part of the right sternoclavicular articulation, and passes upward and lateralward to the medial margin of the m. scalenus anterior. It ascends a little above the clavicle, the extent to which it does so varying in different cases. It is covered, in front, by the integument, superficial fascia, m. platysma, deep fascia, the clavicular origin of the m. sternocleidomastoideus, the m. sternohyoideus, and m. sternothyreoideus, and another layer of the deep fascia. It is crossed by the internal jugular and vertebral veins, by the vagus nerve and the cardiac branches of the vagus and sympathetic, and by the subclavian loop of the sympathetic trunk which forms a ring around the vessel. The anterior jugular vein is directed lateralward in front of the artery, but is separated from it by the m. sternohyoideus and m. sternothyreoideus. Below and behind the artery is the pleura, which separates it from the apex of the lung; behind is the sympathetic trunk, the m. longus collii and the first thoracic vertebra. The right recurrent nerve winds around the lower and back part of the vessel.

The first part of the left subclavian artery arises from the arch of the aorta, behind the left common carotid, and at the level of the fourth thoracic vertebra; it ascends in the superior mediastinal cavity to the root of the neck and then arches lateralward to the medial border of the m. scalenus anterior. It is in relation, in front, with the vagus, cardiac, and phrenic nerves, which lie parallel with it, the left common carotid artery, left internal jugular and vertebral veins, and the commencement of the left innominate vein, and is covered by the m. sternothyreoideus, m. sternohyoideus, and m. sternocleidomastoideus; behind, it is in relation with the esophagus, thoracic duct, left recurrent nerve, inferior cervical ganglion of the sympathetic trunk, and m. longus colli; higher up, however, the esophagus and thoracic duct lie to its right side; the latter ultimately arching over the vessel to join the angle of union between the subclavian and internal jugular veins. Medial to it are the esophagus, trachea, thoracic duct, and left recurrent nerve; lateral to it, the left pleura and lung.

The second portion of the subclavian artery lies behind the m. scalenus anterior; it is very short, and forms the highest part of the arch described by the vessel. It is covered, in front, by the skin, superficial fascia, m. platysma, deep cervical fascia, m. sternocleidomastoideus, and m. scalenus anterior. On the right side of the neck the phrenic nerve is separated from the second part of the artery by the m. scalenus anterior, while on the left side it crosses the first part of the artery close to the medial edge of the muscle. Behind the vessel are the pleura and the m. scalenus medius; above, the brachial plexus of nerves; below, the pleura. The subclavian vein lies below and in front of the artery, separated from it by the m. scalenus anterior.

The third portion of the subclavian artery runs downward and lateralward from the lateral margin of the m. scalenus anterior to the outer border of the first rib, where it becomes the axillary artery. This is the most superficial portion of the vessel, and is contained in the subclavian triangle. It is covered, in front, by the skin, the superficial fascia, the m. platysma, the supraclavicular nerves, and the deep cervical fascia. The external jugular vein crosses its medial part and receives the transverse scapular, transverse cervical, and anterior jugular veins, which frequently form a plexus in front of the artery. Behind the veins, the nerve to the m. subclavius descends in front of the artery. The terminal part of the artery lies behind the clavicle and the m. subclavius and is crossed by the transverse scapular vessels. The subclavian vein is in front of and at a slightly lower level than the artery. Behind, it lies on the lowest trunk of the brachial plexus, which intervenes between it and the m. scalenus medius. Above and to its lateral side are the upper trunks of the brachial plexus and the m. omohyoideus. Below, it rests on the upper surface of the first rib.

The collateral circulation is carried on by: (1) the anastomosis between the superior and inferior thyroids; (2) the anastomosis of the two vertebrals; (3) the anastomosis of the internal thoracic with the inferior epigastric and the aortic intercostals; (4) the costocervical anastomosing with the aortic intercostals; (5) the transversa colli anastomosing with the descending branch of the occipital; (6) the scapular branches of the thyrocervical trunk anastomosing with the branches of the axillary, and (7) the thoracic branches of the axillary anastomosing with the aortic intercostals.

The branches of the subclavian artery are:

First Part	**Second Part**	**Third Part**
Vertebral	Costocervical trunk	Transversa colli
Thyrocervical trunk		
Internal thoracic		

On the left side all branches generally arise from the first portion of the vessel; but on the right side, the costocervical trunk usually springs from the second portion of the vessel. On both sides of the neck, the first three branches arise close together at the medial border of the m. scalenus anterior; in the majority of cases, a free interval of from 1.25 to 2.5 cm. exists between the commencement of the artery and the origin of the nearest branch.

1. The vertebral artery (a. vertebralis), is the first branch of the subclavian, and arises from the upper and back part of the first portion of the vessel. It is surrounded by a plexus of nerve fibers derived from the inferior cervical ganglion of the sympathetic trunk, and ascends through the foramina in the transverse processes of the upper six cervical vertebrae, it then winds behind the superior articular process of the atlas and, entering the skull through the foramen magnum, unites, at the lower border of the pons, with the vessel of the opposite side to form the basilar artery. The vertebral artery may be divided into **four parts**: The **first part** runs upward and backward between the m. longus colli and the m. scalenus anterior. In front of it are the internal jugular and vertebral veins, and it is crossed by the inferior thyroid artery; the left vertebral is crossed by the thoracic duct also. Behind it are the transverse process of the seventh cervical vertebra, the sympathetic trunk and its inferior cervical ganglion. The **second part** runs upward through the foramina in the transverse processes of the upper six cervical vertebrae, and is surrounded by branches from the inferior cervical sympathetic ganglion and by a plexus of veins which unite to form the vertebral vein at the lower part of the neck. It is situated in front of the trunks of the cervical nerves, and pursues an almost vertical course as far as the transverse process of the atlas, above which it runs upward and lateralward to the foramen in the transverse process of the atlas. The **third part** issues from the latter foramen on the medial side of the Rectus capitis lateralis, and curves backward behind the superior articular process of the atlas, the anterior ramus of the first cervical nerve being on its medial side; it then lies in the groove on the upper surface of the posterior arch of the atlas, and enters the vertebral canal by passing beneath the posterior atlantoöccipital membrane. This part of the artery is covered by the m. semispinalis capitis and is contained in the **suboccipital triangle -** a triangular space bounded by the m. rectus capitis posterior major, the m. obliquus superior, and the m. obliquus inferior. The first cervical or suboccipital nerve lies between the artery and the posterior arch of the atlas. The **fourth part** pierces the dura mater and inclines medialward to the front of the medulla oblongata; it is placed between the hypoglossal nerve and the anterior root of the first cervical nerve and beneath the first digitation of the ligamentum denticulatum. At the lower border of the pons it unites with the vessel of the opposite side to form the basilar artery. The branches of the vertebral artery may be divided into two sets: those given off in the neck, and those within the cranium.

- **Spinal branches** (rami spinales) enter the vertebral canal through the intervertebral foramina, and each divides into two branches. Of these, one passes along the roots of the nerves to supply the medulla spinalis and its membranes, anastomosing with the other arteries of the medulla spinalis; the other divides into an ascending and a descending branch, which unite with similar branches from the arteries above and below, so that two lateral anastomotic chains are formed on the posterior surfaces of the bodies of the vertebrae, near the attachment of the pedicles. From these anastomotic chains branches are supplied to the periosteum and the bodies of the vertebrae, and others form communications with similar branches from the opposite side; from these communications small twigs arise which join similar branches above and below, to form a central anastomotic chain on the posterior surface of the bodies of the vertebrae.
- **Muscular branches** are given off to the deep muscles of the neck, where the vertebral artery curves around the articular process of the atlas. They anastomose with the occipital, and with the ascending and deep cervical arteries.

- **The meningeal branch** (ramus meningeus) springs from the vertebral opposite the foramen magnum, ramifies between the bone and dura mater in the cerebellar fossa, and supplies the falx cerebelli. It is frequently represented by one or two small branches.
- **The posterior spinal artery** (a. spinalis posterior) arises from the vertebral, at the side of the medulla oblongata; passing backward, it descends on this structure, lying in front of the posterior roots of the spinal nerves, and is reinforced by a succession of small branches, which enter the vertebral canal through the intervertebral foramina; by means of these it is continued to the lower part of the medulla spinalis, and to the cauda equina. Branches from the posterior spinal arteries form a free anastomosis around the posterior roots of the spinal nerves, and communicate, by means of very tortuous transverse branches, with the vessels of the opposite side. Close to its origin each gives off an ascending branch, which ends at the side of the fourth ventricle.
- **The anterior spinal artery** (a. spinalis anterior) is a small branch, which arises near the termination of the vertebral, and, descending in front of the medulla oblongata, unites with its fellow of the opposite side at the level of the foramen magnum. A. basilaris, two vertebral arteries joined in one trunk and two aa. spinales anteriores also joined in one trunk, form **Zakharchenko's** arterial circle, which, together with circulus arteriosus cerebri, is important in the collateral circulation of the medulla oblongata. One of these vessels is usually larger than the other, but occasionally they are about equal in size. The single trunk, thus formed, descends on the front of the medulla spinalis, and is reinforced by a succession of small branches which enter the vertebral canal through the intervertebral foramina; these branches are derived from the vertebral and the ascending cervical of the inferior thyroid in the neck; from the intercostals in the thorax; and from the lumbar, iliolumbar, and lateral sacral arteries in the abdomen and pelvis. They unite, by means of ascending and descending branches, to form a single anterior median artery, which extend as far as the lower part of the medulla spinalis, and is continued as a slender twig on the filum terminale. This vessel is placed in the pia mater along the anterior median fissure; it supplies that membrane, and the substance of the medulla spinalis, and sends off branches at its lower part to be distributed to the cauda equina.
- **The posterior inferior cerebellar artery** (a. cerebelli inferior posterior), the largest branch of the vertebral, winds backward around the upper part of the medulla oblongata, passing between the origins of the vagus and accessory nerves, over the inferior peduncle to the under surface of the cerebellum, where it divides into two branches. The **medial branch** is continued backward to the notch between the two hemispheres of the cerebellum; while the **lateral** supplies the under surface of the cerebellum, as far as its lateral border, where it anastomoses with the anterior inferior cerebellar and the superior cerebellar branches of the basilar artery. Branches from this artery supply the choroid plexus of the fourth ventricle.
- **The medullary arteries** (bulbar arteries) are several minute vessels which spring from the vertebral and its branches and are distributed to the medulla oblongata.

The **basilar artery** (a. basilaris), so named from its position at the base of the skull, is a single trunk formed by the junction of the two vertebral arteries: it extends from the lower to the upper border of the pons, lying in its median groove, under cover of the arachnoid. It ends by dividing into the two posterior cerebral arteries. Its **branches,** on either side, are the following:

- The **pontine branches** (*rami pontini*) are a number of small vessels which come off at right angles from either side of the basilar artery and supply the pons and adjacent parts of the brain.
- The **internal auditory artery** (a. auditiva interna), a long slender branch, arises from near the middle of the artery; it accompanies the acoustic nerve through the internal acoustic meatus, and is distributed to the internal ear.
- The **anterior inferior cerebellar artery** (a. cerebelli inferior anterior) passes backward to be distributed to the anterior part of the under surface of the cerebellum, anastomosing with the posterior inferior cerebellar branch of the vertebral.
- The **superior cerebellar artery** (a. cerebelli superior) arises near the termination of the basilar. It passes lateralward, immediately below the oculomotor nerve, which separates it from the posterior cerebral artery, winds around the cerebral peduncle, close to the trochlear nerve, and, arriving at the upper surface of the cerebellum, divides into branches which ramify in the pia mater and anastomose with those of the

inferior cerebellar arteries. Several branches are given to the pineal body, the anterior medullary velum, and the tela chorioidea of the third ventricle.

- The **posterior cerebral artery** (a. cerebri posterior) is larger than the preceding, from which it is separated near its origin by the oculomotor nerve. Passing lateralward, parallel to the superior cerebellar artery, and receiving the posterior communicating from the internal carotid, it winds around the cerebral peduncle, and reaches the tentorial surface of the occipital lobe of the cerebrum, where it breaks up into branches for the supply of the temporal and occipital lobes.

  The **branches** of the posterior cerebral artery are divided into two sets, **ganglionic** and **cortical:**
  - **Ganglionic. -** The **postero-medial ganglionic branches** are a group of small arteries which arise at the commencement of the posterior cerebral artery: these, with similar branches from the posterior communicating, pierce the posterior perforated substance, and supply the medial surfaces of the thalami and the walls of the third ventricle. The **posterior choroidal branches** run forward beneath the splenium of the corpus callosum, and supply the tela chorioidea of the third ventricle and the choroid plexus. The **postero-lateral ganglionic branches** are small arteries which arise from the posterior cerebral artery after it has turned around the cerebral peduncle; they supply a considerable portion of the thalamus.
  - **The cortical branches** are: the **anterior temporal,** distributed to the uncus and the anterior part of the fusiform gyrus; the **posterior temporal,** to the fusiform and the inferior temporal gyri; the **calcarine,** to the cuneus and gyrus lingualis and the back part of the convex surface of the occipital lobe; and the **parietoöccipital,** to the cuneus and the precuneus.

2. The thyrocervical trunk (truncus thyreocervicalis; thyriobicervicoscapular trunk) is a short thick trunk, which arises from the front of the first portion of the subclavian artery, close to the medial border of the m. scalenus anterior, and divides almost immediately into three branches, the **inferior thyroid, suprascapular, ascending cervical** and **superficial cervical.**

- The **inferior thyroid artery** (a. thyreoidea inferior) passes upward, in front of the vertebral artery and m. longus colli; then turns medialward behind the carotid sheath and its contents, and also behind the sympathetic trunk, the middle cervical ganglion resting upon the vessel. Reaching the lower border of the thyroid gland it divides into two branches, which supply the postero-inferior parts of the gland, and anastomose with the superior thyroid, and with the corresponding artery of the opposite side. The recurrent nerve passes upward generally behind, but occasionally in front, of the artery.
- The **branches** of the inferior thyroid are:
- The **inferior laryngeal artery** (a. laryngea inferior) ascends upon the trachea to the back part of the larynx under cover of the m. constrictor pharyngis inferior, in company with the recurrent nerve, and supplies the muscles and mucous membrane of this part, anastomosing with the branch from the opposite side, and with the superior laryngeal branch of the superior thyroid artery.
- The **tracheal branches** (rami tracheales) are distributed upon the trachea, and anastomose below with the bronchial arteries.
- The **esophageal branches** (rami aesophagei) supply the esophagus, and anastomose with the esophageal branches of the aorta.
- The **ascending cervical artery** (a. cervicalis ascendens) is a small branch which arises from the inferior thyroid as that vessel is passing behind the carotid sheath; it runs up on the anterior tubercles of the transverse processes of the cervical vertebrae in the interval between the m. scalenus anterior and m. longus capitis. To the muscles of the neck it gives twigs which anastomose with branches of the vertebral, and it sends one or two spinal branches into the vertebral canal through the intervertebral foramina to be distributed to the medulla spinalis and its membranes, and to the bodies of the vertebrae, in the same manner as the spinal branches from the vertebral. It anastomoses with the ascending pharyngeal and occipital arteries.
- The **muscular branches** supply the depressors of the hyoid bone, and the m. longus colli, m. scalenus anterior, and m. constrictor pharyngis inferior.
- The **suprascapular artery** (a. suprascapular artery) passes at first downward and lateralward across the m. scalenus anterior and phrenic nerve, being covered by the m. sterno-cleidomastoideus; it then crosses

the subclavian artery and the brachial plexus, and runs behind and parallel with the clavicle and m. subclavius, and beneath the inferior belly of the m. omohyoideus, to the superior border of the scapula; it passes over the superior transverse ligament of the scapula which separates it from the suprascapular nerve, and enters the supraspinatous fossa. In this situation it lies close to the bone, and ramifies between it and the Supraspinatus, to which it supplies branches. It then descends behind the neck of the scapula, through the great scapular notch and under cover of the inferior transverse ligament, to reach the infraspinatous fossa, where it anastomoses with the scapular circumflex and the descending branch of the transverse cervical. Besides distributing branches to the m. sternocleidomastoideus, m. subclavius, and neighboring muscles, it gives off a **suprasternal branch,** which crosses over the sternal end of the clavicle to the skin of the upper part of the chest; and an **acromial branch,** which pierces the m. trapezius and supplies the skin over the acromion, anastomosing with the thoracoacromial artery (ramus acromialis). As the artery passes over the superior transverse ligament of the scapula, it sends a branch into the subscapular fossa, where it ramifies beneath the m. subscapularis, and anastomoses with the subscapular artery and with the descending branch of the transverse cervical. It also sends articular branches to the acromioclavicular and shoulder-joints, and a nutrient artery to the clavicle.

3. The internal thoracic artery (a. thoracica interna) arises from the under surface of the first portion of the subclavian, opposite the thyrocervical trunk. It descends behind the cartilages of the upper six ribs at a distance of about 1.25 cm. from the margin of the sternum, and at the level of the sixth intercostal space divides into the **musculophrenic** and **superior epigastric arteries.** It is directed at first downward, forward, and medialward behind the sternal end of the clavicle, the subclavian and internal jugular veins, and the first costal cartilage, and passes forward close to the lateral side of the innominate vein. As it enters the thorax the phrenic nerve crosses from its lateral to its medial side. Below the first costal cartilage it descends almost vertically to its point of bifurcation. It is covered in front by the cartilages of the upper six ribs and the intervening Intercostales interni and anterior intercostal membranes, and is crossed by the terminal portions of the upper six intercostal nerves. It rests on the pleura, as far as the third costal cartilage; below this level, upon the m. transversus thoracis. It is accompanied by a pair of veins; these unite above to form a single vessel, which runs medial to the artery and ends in the corresponding innominate vein. The branches of the internal thoracic are:

- **The pericardiacophrenic artery** (a. pericardiacophrenica) is a long slender branch, which accompanies the phrenic nerve, between the pleura and pericardium, to the diaphragm, to which it is distributed; it anastomoses with the musculophrenic and inferior phrenic arteries.
- **The anterior mediastinal arteries** (aa. mediastinales anteriores; mediastinal arteries) are small vessels, distributed to the areolar tissue and lymph glands in the anterior mediastinal cavity, and to the remains of the thymus.
- **The pericardial branches** supply the upper part of the anterior surface of the pericardium; the lower part receives branches from the musculophrenic artery.
- **The sternal branches** (rami sternales) are distributed to the m. transversus thoracis, and to the posterior surface of the sternum.

The anterior mediastinal, pericardial, and sternal branches, together with some twigs from the pericardiacophrenic, anastomose with branches from the intercostal and bronchial arteries, and form a **subpleural mediastinal plexus.**

- The **intercostal branches** (rami intercostales; anterior intercostal arteries) supply the upper five or six intercostal spaces. Two in number in each space, these small vessels pass lateralward, one lying near the lower margin of the rib above, and the other near the upper margin of the rib below, and anastomose with the intercostal arteries from the aorta. They are at first situated between the pleura and the m. intercostales interni, and then between the m. intercostales interni and externi. They supply the Intercostales and, by branches which perforate the m. intercostales externi, the m. pectorales and the mammary gland.
- The **perforating branches** (rami perforantes) correspond to the five or six intercostal spaces. They pass forward through the intercostal spaces, and, curving lateralward, supply the m. pectoralis major and the integument. Those which correspond to the second, third, and fourth spaces give branches to the mammary gland, and during lactation are of large size.
- The **musculophrenic artery** (a. musculophrenica) is directed obliquely downward and lateralward, behind the cartilages of the false ribs; it perforates the diaphragm at the eighth or ninth costal cartilage, and ends,

considerably reduced in size, opposite the last intercostal space. It gives off intercostal branches to the seventh, eighth, and ninth intercostal spaces; these diminish in size as the spaces decrease in length, and are distributed in a manner precisely similar to the intercostals from the internal thoracic. The musculophrenic also gives branches to the lower part of the pericardium, and others which run backward to the diaphragm, and downward to the abdominal muscles.

- The **superior epigastric artery** (a. epigastrica superior) continues in the original direction of the internal mammary; it descends through the interval between the costal and sternal attachments of the diaphragm, and enters the sheath of the m. rectus abdominis, at first lying behind the muscle, and then perforating and supplying it, and anastomosing with the inferior epigastric artery from the external iliac. Branches perforate the anterior wall of the sheath of the m. rectus, and supply the muscles of the abdomen and the integument, and a small branch passes in front of the xiphoid process and anastomoses with the artery of the opposite side. It also gives some twigs to the diaphragm, while from the artery of the right side small branches extend into the falciform ligament of the liver and anastomose with the hepatic artery.

4. The costocervical trunk (truncus costocervicalis) arises from the upper and back part of the subclavian artery, behind the Scalenus anterior on the right side, and medial to that muscle on the left side. Passing backward, it gives off the **a. profunda cervicalis** (a. cervicalis profunda)**,** and, continuing as the **a. highest intercostal artery** (a. intercostalis suprema), descends behind the pleura in front of the necks of the first and second ribs, branches into the first and second intercostal spaces and anastomoses with the first aortic intercostal. As it crosses the neck of the first rib it lies medial to the anterior division of the first thoracic nerve, and lateral to the first thoracic ganglion of the sympathetic trunk.

5. The transverse cervical artery (a. transversa colli) lies at a higher level than the transverse scapular; it passes transversely above the inferior belly of the m. omohyoideus to the anterior margin of the m. trapezius, beneath which it divides into an **ascending (superficial)** and a **descending (deep) branch.** It crosses in front of the phrenic nerve and the m. scaleni, and in front of or between the divisions of the brachial plexus, and is covered by the m. platysma and m. sternocleidomastoideus, and crossed by the m. omohyoideus and m. trapezius.

- The **ascending branch** (*ramus ascendens; superficial cervical artery*) ascends beneath the anterior margin of the m. trapezius, distributing branches to it, and to the neighboring muscles and lymph glands in the neck, and anastomosing with the superficial branch of the descending ramus of the occipital artery. The ascending branch of the transverse cervical frequently arises directly from the thyrocervical trunk; and the descending branch from the third, more rarely from the second, part of the subclavian.
- The **descending branch** (*ramus descendens; posterior (dorsal) scapular artery*) passes beneath the m. levator scapulae to the medial angle of the scapula, and then descends under the m.m. rhomboidei along the vertebral border of that bone as far as the inferior angle. It supplies the m.m. rhomboidei, m. latissimus dorsi and m. trapezius, and anastomoses with the transverse scapular and subscapular arteries, and with the posterior branches of some of the intercostal arteries.

Arteries of the upper extremity

The axillary artery

The axillary artery (a. axillaris) is a direct continuation of the subclavian artery. In turn, a. axillaris is continuous with the brachial artery. The proximal border of the trunk of the axillary artery is on a level with the external edge of the first rib. The distal border is on the inferior edge of m. teres major (at the origin of the brachial artery) and inferior margine of m. pectoralis major. The axillary artery lies in the axillary cavity, which is medial of the shoulder joint and the humerus; in front and medial of it is v. axillaris with the nerve trunks of the brachial plexus on three sides. At its lower end this neurovascular bundle is covered with skin, fascia, and fatty tissue containing lymphatic nodes.

Three topographical segments of a. axillaris are distinguished along its length:

1) the **trigonum clavipectorale**, from the clavicle to the superior margin of m. pectoralis minor;

2) the **trigonum pectorals**, posteriorly of m. pectoralis minor; and

3) the **trigonum subpectorale**, from the inferior margin of m. pectoralis minor to the inferior margin of m. pectoralis major.

The branches of a. axillaris in the **trigonum clavipectorale**:

1. The **superior thoracic artery** (a. thoracica suprema) branches out in m. subclavius, both pectoral muscles, m. serratus anterior, and the nearest intercostal muscles.

2. The **thoraco-acromial artery** (a. thoracoacromialis) originates at the superior margin of m. pectoralis minor and divides into branches, some of which pass upward and laterally to the acromion. Projecting forward to the upper border of pectoralis major, it pierces the coracoclavicular fascia and divides in subclavicular fossa into four branches **- pectoral, acromial, clavicular,** and **deltoid**. There they anastomose with a. suprascapularis to form a network of vessels that take part in supplying the shoulder joint with blood.

In the trigonum pectorale:

3. The **lateral thoracic artery** (a. thoracica lateralis) descends on the lateral wall of the chest and gives off branches to the mammary gland and the surrounding muscles. It anastomoses with the a. internal thoracic, a. subscapular, and intercostal arteries, and with the pectoral branch of the thoracoacromial artery.

In the **trigonum subpectorale**:

4. The **subscapular artery** (a. subscapularis) is the largest branch of the axillary artery. It rises near the inferior border of the subscapular artery and descends along this artery, giving off branches to it; the subscapular artery soon separates into two trunks:

a) **a. circumflexa scapulae**, which passes through the **foramen trilaterum** to the dorsal surface of the scapula where it anastomoses with a. suprascapularis; and

b) **a. thoracodorsalis**, which is a continuation of the subscapular artery and passes along the lateral border of the scapula.it supplies adjiacent muscles, principially the latissimus dorsi.

5. The **posterior circumflex humeral artery** (a. circumflexa humeri posterior) passes to the back with the axillary nerve into the **foramen quadrilaterum.** It winds around the surgical neck of the humerus and is distributed to the m. deltoideus and shoulder-joint, anastomosing with the anterior humeral circumflex and profunda brachii arteries.

6. The **anterior circumflex humeral artery** (a. circumflexa humeri anterior) curves around the humerus. Smaller than the posterior circumflex artery, it begins on the same level and passes in the lateral direction, curving round the neck of the humerus anteriorly, anastomosing with a. circumflexa humeri posterior, and giving off branches to the muscles and the sholder joint.

All the branches of the axillary artery anastomose widely with branches of the subclavian artery. Ligation of the axillary artery above the point where a. subscapularis branches off is, therefore, more effective than when ligation is lower. Similarly, ligation of the subclavian artery at its origin often results in gangrene, whereas ligation distally from the origin at the truncus thyrocervicalis does not lead to such complications.

The brachial artery

The **brachial artery** (a. brachialis) is continuous with the axillary artery. Beginning at the lower border of m. teres major, it leads to the sulcus bicipitalis medialis where, at the level of the neck of the radius (elbow joint), it divides into its terminal branches: the **radial** and **ulnar** arteries. On its way to the sulcus bicipitalis medialis, it is attended by two brachial veins and nerves (n. medianus, n. ulnaris, n. cutaneus brachii medialis, and n. cuta- neus antebrachii medialis). In addition to sending off small branches to the bone and muscles, the brachial artery gives rise to the following branches:

1. The **profunda brachii artery** (a. profunda brachii) rises from a. brachialis soon after the origin of the latter; it is a large branch that, together with n. radialis, passes into the canalis spiralis (canalis nervi radialis seu canalis humeromuscularis). The deep brachial artery gives off an artery that supplies the brachial bone with nutrients (a. diaphyseos humeri). The deep brachial artery also gives off posterior descending branch (**a. collateralis media**), which penetrates the thickness of m. triceps and anastomoses with **a. interossea recurrens** (from a. interossea posterior) and with anterior descending branch (**a. collateralis radialis**). The latter emerges onto the surface through the inferior opening of the canalis spiralis, advancing forward from the epicondylus lateralis and anastomosing with **a. recurrens radialis**. A. profunda brachii arises with other branches of the brachial or axillary arteries in 50 per cent of cases. In 30 per cent of all cases, it is altogether missing.

2. The **superior ulnar collateral artery** (a. collateralis ulnaris superior) rises from the brachial artery in the middle of the arm or somewhat higher and settles into the sulcus behind the epicondylus medialis with ulnar nerve, where it anastomoses with **a. recurrens ulnaris posterior** (branch of a. ulnaris).

2. The **inferior ulnar artery** (a. collateralis ulnaris inferior) rises from the medial semicircle of the brachial artery about 5 cm above the end of the latter. Obliquely passing over the surface of m. brachialis in a

medial and distal direction, this artery anastomoses anteriorly of the epicondylus medialis with **a. recurrens ulnaris anterior** (branch of a. ulnaris).

The radial artery

The **radial artery** (a. radialis) is directly continuous with the brachial artery. It passes medially of m. brachioradialis, at first under its cover and then in the sulcus radialis. In the lower one-third of the ante-brachium where the muscles become tendons, a radial artery is covered only by the fascia and skin. The pulse can be easily taken here since the artery is so close to the surface. On reaching the top of the styloid process of the radial bone, a. radialis passes to the back of the hand, curving around the lateral edge of the carpus and settling into the anatomical “snuff-box” from where it exits onto the palm through the first interosseous space between the bases of the first and second metacarpal bones. On the palm, a. radialis, together with the deep branch of the ulnar artery, forms the **the deep palmar arch (**arcus palmaris profundus).

The branches of the radial artery:

1. The **radial recurrent artery** (a. reccurens radialis) originates in the cubital fossa and passes in the proximal direction toward the anterior surface of the lateral epicondyle where it anastomoses with the above mentioned **a. collateralis radialis** from a. profundae brachii.

2. **Muscular branches** (rami musculares) supply the surrounding muscles with blood.

3. The **anterior carpal branch** (ramus carpeus palmaris) originates in the lower part of the foream and passes to meet a similar branch rising from a. ulnaris. The anastomosis of the ramus carpeus palmaris and a. ulnaris results in **rete carpi palmare** on the surface of the palm.

4. The **superficial palmar branch** (ramus palmaris superficialis) either **passes over** the thenar eminence or **penetrates** its superficial layers and, joining the end of the ulnar artery, participates in the formation of the arcus palmaris superficialis.

5. The **posterior carpal branch** (ramus carpeus dorsalis) rises from the region of the anatomical "snuffbox" and, with the a. ulnaris branch, forms a network, the **rete carpi dorsale**, which also receives small branches from the **interosseous arteries** (aa. interosseae anterior and posterior).

6. The **first dorsal metacarpal artery** (a. metacarpea dorsalis prima) passes over the dorsal surface of the hand to the radial side of the index finger and to both sides of the thumb.

7. The **princeps pollicis artery** (a. princeps pollicis) branches off the radial artery as soon as the latter penetrates the first interosseous space on the palm of the hand; it runs over the palmar surface of the first metacarpal bone and divides into branches, aa. digitales palmares, to both sides of the thumb and to the radial side of the index finger (**radialis indicis artery**).

The ulnar artery

The **ulnar artery** (a. ulnaris) is the larger of two terminal branches of the brachial artery. From its origin in the cubital fossa (opposite the neck of the radius), it runs under m. pronator teres to the median one-third of the forearm, slanting toward the ulnar side. In the lower two-thirds, it runs parallel to the ulna first in the interval between m. flexor digitorum superficialis and m. flexor carpi ulnaris; in the lower one-third, its position becomes more superficial (**sulcus ulnaris**) as the muscles end in tendons. On the radial side of the pisiform bone, the ulnar artery passes into the **canalis carpi ulnaris** (spatium interaponeuroticum) and, crossing over to the palm, becomes part of **arcus palmaris superficialis**.

The branches of the ulnar artery:

1. The **ulnar recurrent artery** (a. recurrens ulnaris) runs in the proximal direction in the form of two branches, the **ramus anterior** and **posterior**; these branches (could be sepate vessels) run anteriorly and posteriorly of the medial epicondyle anastomosing with **aa. collaterales ulnares superior** and **inferior**. These anastomoses, together with the anastomoses mentioned above, which connect branches a. profunda brachii and a. radialis, result in the arterial network called the **rete articulare cubiti**.

2. The **common interosseous artery** (a. interossea communis) has a short trunk directed toward the interosseous membrane. At the proximal border of the membrane it divides into two branches:

a) **a. interossea anterior** passes along the anterior surface of the interosseous membrane and reaches m. pronator quadratus where it pierces the membrane and recedes to the rear, ending in the rete carpi dorsale. At its origin a. interossea anterior gives off a. mediana (passing toward the palm, together with n. medianus), aa. diaphyseos radii and ulnae to the bones of the forearm, and the rami musculares to the surrounding muscles;

b) **a. interossea posterior** passes through the superior orifice of the interosseous membrane to the dorsal side, gives off **a. interossea recurrens**, and lies between the superficial and deep layers of extensors. In the region of the wrist, a. interossea posterior anastomoses with a. interossea anterior.

3. The **anterior carpal branch** (ramus carpeus palmaris) meets and anastomoses with the palmar carpal branch of the radial artery.

4. The **posterior carpal branch** (ramus carpeus dorsalis) originates near the pisiform bone and passes under m. flexor carpi to the dorsal side to meet the dorsal carpal branch of the radial artery.

5. The **deep palmar branch** (ramus palmaris profundus) passes under the tendons in ulnar carpal canal (Guyon) and nerves of the palm and, together with a. radialis participates in forming the **deep palmar arch**.

The Arches and Arteries of the Hand

There are two networks in the carpal region: palmar, the **rete carpi palmare**, and dorsal, the **rete carpi dorsale**.

The **anterior carpal arch** (rete carpi palmare) is formed by the union of the palmar carpal branches of the radial and ulnar arteries and the branches of the anterior interosseous artery. The palmar network of the carpus lies on the carpal ligaments under the flexor tendons; its branches supply nutrients to the ligaments and the mediocarpal and radiocarpal joints.

The **posterior carpal arch** (rete carpi dorsale) is formed by the union of the dorsal carpal branches of the radial and ulnar and branches of the inter- osseous arteries. It lies under the extensor tendons and gives off branches to: (a) the nearest joints (**rr. articulares**) and (b) the second, third, and fourth interosseous spaces (**aa. metacarpeae dorsales**). At the base of the fingers, each branch divides into branches stretching to the fingers (**aa. digitales dorsales**).

A superficial and a deep arch are located on the palm.

The **superficial palmar arch** (arcus palmaris superficialis) lies under the palmar aponeurosis. A continuation of the ulnar artery, the superficial arch diminishes in calibre as it moves to the radial side where it is joined by the superficial palmar branch of the radial artery. The distal convexity of the superficial arch gives rise to **four aa. digitales palmares communes**. Three of them pass in one line with the second, third, and fourth interosseous space, respectively, while the fourth extends to the ulnar side of the little finger. At the fold of skin between the fingers, each artery divides into **two aa. digitales palmares propriae**, stretching on the contiguous sides of the adjacent fingers.

The **deep palmar arch** (arcus palmaris profundus) lies deep under the flexor tendons on the bases of the metacarpal bones and the ligaments, proximal to the superficial arch. Formed mainly by the radial artery, the deep palmar arch, in contrast to the superficial arch, diminishes in calibre as it moves to the ulnar side of the hand where it is composed of a relatively thin, **deep palmar branch of the ulnar artery**. The convexity of the deep arch gives rise to three arteries extending distally to the three interosseous spaces, beginning with the second space. These are **aa. metacarpeae palmares**, which anastomose with the ends of the common palmar digital arteries at the interdigital folds. The arch also gives rise to three small branches, **aa. perforantes**, which pass dorsally through the interosseous spaces (second, third, and fourth) and anastomose with the dorsal metacarpal arteries on the dorsal surface of the hand. The **recurrent branches** arise from the concavity of the deep palmar arch. They ascend in front of the wrist, supply the intercarpal articulations, and end in the volar carpal network

The **superficial** and **deep arterial arches** are the result of an important functional adjustment. When the hand performs a grasping action, its vessels are often compressed; when the flow of blood in the superficial palmar arch is disturbed, the supply of blood to the hand does not suffer since it flows along the arteries of the deep arch in such cases. The articular networks are the result of similar adjustments: the blood flows freely through these networks to the joint even when the vessels contract and stretch during movements at the joint. There are many possibilities for the development of collateral circulation in the upper limb. The deep brachial artery serves as a collateral vessel for the brachial artery, as does the common interosseous artery for the ulnar artery.

Branches of the descending aorta

The organs of both animal life (the walls of cavities) and vegetative life (the viscera) exist in the human body, and thus the branches of the descending aorta can be classified into the **parietal branches** (rami parietales), stretching to the walls of the cavities, and the **visceral branches** (rami viscerales) , running to the contents of the cavities, the viscera.

Branches of the thoracic aorta

The thoracic segment of the aorta (aorta thoracica), which is the derivative of the dorsal aorta, gives off the following branches.

Rami viscerales:

1. The **bronchial branches** (rami bronchiales), which supply nutrients to the lung as an organ, enter the lungs with the bronchi and carry arterial blood for the lymph nodes and tissue of the lung as far as the alveoli. Some times the bronchial arteries arise from the abdominal aorta.

2. The **oesophageal branches** (rami oesophagei) form anastomoses with the branches of the inferior thyroid artery in the upper section of the oesophageal wall and with the branches of the left gastric artery in the lower section.

3. The **mediastinal branches** (rami mediastinales) pass to the lymph nodes and connective tissue of the posterior mediastinum.

4. The pericardial branches (rami pericardiaci) stretch to the pericardium.

Rami parietales:

The walls of the thoracic cavity are segmented. Ten pairs of **posterior intercostal arteries** III-XI (aa. intercostales posteriores III-XI) branch off from the aorta (posterior intercostal arteries I and II arise from the costocervical trunk). The twelfth posterior intercostal artery passes below the rib; this is the **subcostal artery** (a. subcostalis).

At the beginning of the intercostal spaces, each posterior intercostal artery gives rise to a **dorsal branch** (ramus dorsalis), extending to the **spinal cord, roots of the spinal nerves** and **meninges** (rr. spinals, radiculares et meningei) and to the muscles and skin of the back. The continuation of the initial trunk of the posterior intercostal artery, the **intercostal artery proper**, passes along the costal sulcus. Up to the costal angle the artery is in direct contact with the pleura; after that it lies between the external and internal intercostal muscles, and its ends form anastomoses with the anterior intercostal branches of the **internal thoracic artery**. The lower three intercostal arteries anastomose with the superior **epigastric artery**. The intercostal arteries also provide branches to the muscles, ribs, and skin, and, in females, to the mammary gland.

The **superior phrenic arteries** (aa. phrenicae superiores) are small branches of the thoracic aorta, which branch out on the superior surface of the diaphragm where they form anastomoses with the pericardiacophrenic, musculophrenic (from the internal thoracic artery), aa. phrenicae inferiores and posterior intercostal arteries. All these parietal anastomoses become important in stenosis of the thoracic aorta.

Branches of the abdominal aorta

The **parietal branches** of the abdominal aorta (rami parietales) are paired, except for the median sacral artery, which is actually the caudal segment of the aorta whose development is retarded. The **visceral branches** (rami viscerales) are classified as **paired** or **unpaired**.

The unpaired visceral branches

I. The coeliac artery (truncus celiacus) is a short (2 cm), thick artery rising at the level of the twelfth thoracic vertebra in the hiatus aorticus of the diaphragm. It passes forward above the superior border of the pancreas where it divides into **three branches** (the site of the division is called the tripus celiacus): the **left gastric**, **common hepatic**, and **splenic arteries**.

1. The **left gastric artery** (a. gastrica sinistra) extends to the lesser curvature of the stomach and gives off branches to the stomach (rr.gastrici anteriores et posteriores) and the abdominal part of the oesophagus (r. esophgeus).

2. The **common hepatic artery** (a. hepatica communis) passes along the superior margin of the head of the pancreas to the superior border of the duodenum. There it produces the a. gastroduodenalis which may be multiple. Further it continues as the a. **hepatica propria**, which lies between the two layers of the **hepatoduodenal ligament** in front of the **portal vein** and to the left of the **ductus choledochus**, and reaches the porta hepatis where it divides into **right and left branches** (ramus dexter and ramus sinister). The right branch gives rise to an artery to the gall bladder, **a. cystica**, at the junction of the common hepatic duct and the cystic

duct. The common or proper hepatic artery gives off a branch to the lesser curvature of the stomach, **a. gastrica dextra**, which stretches from right to left to connect **a. gastrica sinistra (**lesser gartric aterial coronal arch**)**. The **gastroduodenal artery** mentioned above passes behind the duodenum and divides into **two branches**: the a. **gastro-epiploica dextra**, which passes from right to left on the greater curvature of the stomach and gives off branches to the stomach and omentum, in whose anterior wall it stretches; and the a. pancreaticoduodenalis superior (chould be two), which branches out in the head of the pancreas and in the descending part of the duodenum.

3. The **splenic artery** (a. lienalis s. splenica) is the largest of the three terminal branches of the coeliac trunk. It passes on the superior border of the pancreas to the spleen. At the spleen it divides into five to eight terminal branches, which enter the hilus lienis. On the way, it gives off the **rami pancreatici** (one is principal). Near the site of its division into terminal branches, the splenic artery gives rise to the a. **gastro-epiploica sinistra**, which passes from left to right on the greater curvature of the stomach and anastomoses with the a. gastroepiploica dextra to form an arterial (inconstant) arch like the arch on the lesser curvature (greater gastric coronal arch). Numerous small branches arise from the arch and run to the stomach (**rr. gastrici anteriores et posteriores**) and to the greater omentum **(rr. epiploici**). In addition, few aa. gastricae breves arise from the splenic artery after it gives off the left gastro-epiploic artery; these short arteries can fully compensate for an impaired flow of blood in the four main arteries of the stomach. Around the stomach the four main arteries form an **arterial ring, or corona**, which consists of two arches situated on the **lesser curvature**, called the left and right gastric arteries, and on the **greater curvature**, called the left and right gastro-epiploic arteries. These main arteries are thus also referred to as the coronary arteries of the stomach.

II. The superior mesenteric artery (a. mesenterica superior) arises from the anterior surface of the aorta directly below the coeliac artery, passes forward and downward into the slit between the inferior border of the pancreas in front and the horizontal part of the duodenum behind, enters the mesentery of the small intestine, and descends to the right iliac fossa.

The branches of the superior mesenteric, artery are as follows:

1. The **inferior pancreaticoduodenal arteries** (aa. pancreaticoduodenales inferiores) pass to the right on the concave surface of the duodenum to meet the superior pancreaticoduodenal arteries;

2. The **intestinal arteries** (aa. intestinales) (ten to sixteen branches) pass to the left, to the jejunum (**aa. jefunales**) and ileum (**aa. ilei**); on the way they split and the neighbouring branches anastomose, as a result of which **three rows** of arches form along aa. jejunales and **two rows** along aa. ilei. The arches are the result of functional adjustments to ensure the supply of blood to the intestine during any movement or position of its loops. The arches encircle the intestinal tube with many fine branches (**rr. recti**);

3. The **ileocolic artery** (a. ileocolica) branches off the superior mesenteric artery to the right, supplies branches to the distal part of the ileum and caecum, and sends the **a. appendicularis**, which passes behind the terminal segment of the ileum, to the vermiform process;

4. The **right colic artery** (a. colica dextra) stretches behind the peritoneum to the ascending colon and divides next to it into two branches - **an ascending branch**, which rises to meet a. colica media, and a **descending branch**, which descends to meet a. ileocolica; the resulting arches send branches to the adjoining parts of the colon;

5. The **middle colic artery** (a. colica media) passes between the layers of the transverse mesocolon and on reaching the transverse colon divides into the **right** and **left branches** which diverge to their respective sides. The right branch anastomoses with a. colica dextra, the left branch with a. colica sinistra (**Riolan arch**).

III. The inferior mesenteric artery (a. mesenterica inferior) branches off on the level of the inferior edge of the third lumbar vertebra (one vertebra above the aortic bifurcation) and passes downward and slightly to the left, lying behind the peritoneum on the anterior surface of the left psoas major muscle. The branches of the inferior mesenteric artery are as follows:

1. The **left colic artery** (a. colica sinistra) divides into two branches, an **ascending branch** passing to the left flexure of the colon to meet the middle colic artery (from the superior mesenteric artery) and a **descending branch** anastomosing with aa. sigmoideae;

2. The **sigmoid arteries** (aa. sigmoideae) (usually two), pass to the sigmoid colon; their ascending branches anastomose with branches of a. colica sinistra, the descending branches with a. rectalis superior;

3. The **superior rectal artery** (a. rectalis superior) is a continuation of the inferior mesenteric artery; it descends in the root of the mesentery of the sigmoid colon into the true pelvis, crossing the left common iliac

artery in front, and divides into lateral branches, which lead to the rectum and anastomose with the sigmoid arteries and with the middle rectal artery (from the internal iliac artery).

As the result of communications between the branches of aa. colicae dextra, media, and sinistra and aa. rectales, the large intestine is attended by a chain of interconnected anastomoses for its entire length.

The paired visceral branches

The **paired visceral** branches arise in the order of the location of organs, which is the result of their embryonic determination.

1. The middle suprarenal artery (a. suprarenalis media) arises from the aorta next to the origin of the superior mesenteric artery and passes to the suprarenal gland.

2. The renal artery (a. renalis) branches off the aorta almost at a right angle at the level of the second lumbar vertebra and passes transversely to the hilum of the corresponding kidney. The calibre of the renal artery is almost equal to that of the superior mesenteric artery, which is explained by the uropoietic function of the kidney for which a rich flow of blood is needed (a quarter of aortic blood). In some cases, the renal artery arises from the aorta in two or three trunks and quite often enters the kidney with many trunks, not only in the region of the hilum but also along the whole medial border (each of these arteries supplies only corresponding them regions of kidney, without inter-connection). This is important to keep in mind in preliminary ligation of the arteries during surgical removal of the kidney.

At the renal hilum, the renal artery separates into arteries according to the parts of the kidney, namely vessels for the upper pole, the **superior polar arteries**, for the lower pole, **inferior polar arteries**, and for the middle part of the kidney, the **central arteries**. In the kidney parenchyma, these arteries pass between the pyramids, i.e. between the lobes of the kidney, and are, therefore, called the **interlobar arteries** (aa. interlobares renis). At the base of the pyramid at the junction of the medulla and cortex, they form arterial arches, the **arciform arteries** (aa. arcuatae), which give rise to the **interlobular arteries** (aa. interlobulares) piercing the cortex. Each interlobular artery gives origin to **vas afferens**, which ramifies to form a tuft of convoluted capillaries, the **glomerulus**, invaginated in the initial part of the renal tubule, the Shumlyansky-Bowman (nephron) capsule. The **vas efferens** emerging from the glomerulus again breaks up into capillaries, which first surround the renal tubules and only after that they are continuous with the veins.

The kidney contains two capillary systems: one connects the arteries with the veins while the other is of a special character comprising a vascular tuft, in which blood is isolated from the capsular cavity by only two layers of squamous cells (the endothelium of the capillaries and the endothelium of the capsule). This provides favourable conditions for the excretion of water and metabolites from blood.

The right renal artery is behind the inferior vena cava, the head of the pancreas, and the descending part of the duodenum. The left artery passes behind the pancreas. The renal vein lies in front of and somewhat lower than the artery. The renal artery gives rise to the **a. suprarenalis inferior**, ascending to the inferior part of the suprarenal gland, and also gives off a small branch to the ureter (a ureterica).

3. The testicular artery (a. testicularis) is a long, slender vessel rising from the aorta directly below the origin of the renal artery or, sometimes, from the renal artery itself. The origin of the artery that supplies the testis is located so high because the testis develops in the embryo in the lumbar region where, at the shortest distance from the aorta, the testicular artery appears. When the testis later descends into the scrotum, the testicular artery is simultaneously extended. By the time of birth, this artery descends on the anterior surface of the psoas major muscle, sends a branch to the ureter, approaches the deep inguinal ring, and, together with the ductus deferens, reaches the testis, hence the name testicular artery. The **ovarian artery** (a. ovarica), the corresponding artery in females, does not enter the inguinal canal but passes into the true pelvis (here is close to ureter) and then to the ovary as a component of the suspensory ligament.

The parietal branches of the abdominal aorta

1. The **inferior phrenic artery** (a. phrenica inferior) supplies blood to the lumbar part of the diaphragm. It gives rise to few branches, aa. suprarenalis superiores, to the adrenal gland.

2. The **lumbar arteries** (aa. lumbales), usually **four** on each side (a fifth artery sometimes arises from a. sacralis -mediana), correspond to the segmental intercostal arteries of the thoracic region. They supply blood to the corresponding vertebrae, the spinal cord (rr. spinalis, the main is Adamkiewicz artery), and the muscles and skin of the back and abdomen and anastomose with each other, with the inferior intercostal and the superior and

inferior epigastric arteries.

3. The **median sacral artery** (a. sacralis medians), which is an unpaired vessel, is a continuation of the aorta that fails to develop (caudal aorta). It descends on the anterior midline of the two lower lumbar vertebrae, sacrum and coccyx, and terminates here as small branches in the coccygeal body (glomus coccygeum).

The common iliac artery

The common iliac artery (a. iliaca communis). The **right** and **left** arteries are two terminal branches into which the aorta divides at the level of the **fourth lumbar vertebra**. The division occurs slightly to the left of the midline, as a result of which the right common iliac artery is 6-7 mm longer than the left artery. From the site of the **bifurcation** (bifurcatio aortae), the common iliac arteries diverge at an acute angle (approximately 60 degrees in males and 68-70 degrees in females due to the wider female pelvis) and pass downward and laterally to the sacroiliac joint. Here each artery divides into two end branches: the **internal iliac artery** (a. iliaca interna), supplying the walls and organs of the pelvis with blood, and the **external iliac artery** (a. iliaca externs), serving mainly the lower limb. The common iliac arteries originate as the initial segments of the umbilical arteries of the embryo. The distally located segments of the embryonal umbilical arteries are obliterated in the adult and transform into ligamenta umbilicalia mediales.

The internal iliac artery

The **internal iliac artery** (a. iliaca interna), arising from the distal end of the common iliac artery at the level of the sacroiliac joint, descends into the true pelvis and extends to the superior edge of the greater sciatic foramen. Its division into **parietal** and **visceral branches** is marked by wide individual variation, but it usually divides at the level of the superior edge of the greater sciatic foramen into two main branches: the **posterior trunk**, which gives rise to **aa. iliolumbalis**, **sacralis lateralis**, and **glutea superior**, and the **anterior trunk**, from which the remaining branches of the internal iliac artery rise. The internal iliac artery is covered along its length by the peritoneum, and in front of it extends the ureter. This must be keep in mind during surgery to avoid ligation of the ureter instead of the artery; the internal iliac vein passes behind the artery.

The parietal branches of the internal iliac artery:

1. The **iliolumbar artery** (a. iliolumbalis) runs behind m. psoas major into the iliac fossa where its iliac branch forms an anastomosis with the deep circumflex iliac artery rising from the external iliac artery. Lumbar branch joints with last lumar artery

2. The **lateral sacral artery** (a. sacralis lateralis) (sometimes could be two arteries on each side) supplies blood to the levator and the piriform muscles and the nerve trunks of the sacral plexus and gives off branches, the rami spinales, to the foramina sacralia pelvina; it anastomoses with the median sacral artery.

3. The **superior gluteal artery** (a. glutea superior) is a continuation of the posterior division of the internal iliac artery. It leaves the pelvis through the foramen suprapiriforme and reaches the gluteal muscle along with the superior gluteal nerve.

4. The **obturator artery** (a. obturatoria) passes to the obturator foramen. Before entering the obturator canal it gives off the **ramus pubicus**, which extends on the posterior surface of the pubic bone and anastomoses with the **ramus pubicus** of the inferior epigastric artery. The branch in this course usually lies in contact with the external iliac vein, and on the lateral side of the femoral ring; in such cases it would not be endangered in the operation for strangulated femoral hernia. Occasionally, however, it curves along the free margin of the lacunar ligament, and if in such circumstances a femoral hernia occurred, the vessel would almost completely encircle the neck of the hernial sac **(corona mortis)**, and would be in great danger of being wounded if an operation were performed for strangulation.On leaving the obturator canal it supplies the external obturator muscle and the adductors and gives rise to the ramus acetabularis. The latter penetrates the hip joint through the acetabular notch and supplies the head of the femur by its ligaments (lig. capitis femoris).

5. The **inferior gluteal artery** (a. glutea inferior) passes through the foramen infrapiriforme with the internal pudendal artery and the sciatic nerve and gives off a long, slender branch, the companion artery of the sciatic nerve (a. comitans n. ischiadici), to the latter. On leaving the pelvic cavity the inferior gluteal artery gives rise both to muscular branches (which lead to the gluteal and other proximate muscles) and anastomosing branches (which join with the obturator, superior gluteal, and medial circumflex femoral arteries).

The visceral branches of the internal iliac artery:

1. The **umbilical artery** (a. umbilicalis) retains its lumen in the adult only for a small distance, from its

origin to the site where it gives off the superior vesical artery; the remaining segment of its trunk to the umbilicus obliterates and transforms into the medial umbilical ligament.

2. The ureteric branches (rami ureterici) go to the ureter (these may arise from the umbilical artery).

3. The **superior** and **inferior vesical arteries** (aa. vesicales superior and inferior); the superior vesical artery arises from the umbliterated part of a, umbilicalis and branches out in the upper part of the urinary bladder; the inferior vesical artery originates from a. iliacae internae and supplies the ureter and the fundus of the urinary bladder with blood, anastomosing with the superior vesical arteries. It also gives off branches to the vagina (in females) and to the prostate and seminal vesicles (in males).

4. The **artery of vas deferens** (a. ductus deferentis); the ductus deferentis artery in males runs to the ductus deferens and, accompanied by it, reaches the testis, to which it also gives, off branches anastomosing with the testicular artery.

5. The **uterine artery** (a. uterina) (originates either from the trunk of a. iliacae internae or from the beginning segment of a. umbilicalis, passes medially, and, reaching the lateral side of the uterine neck between the two layers of lig. latum uteri, sends a branch, **a. vaginalis**, downward (it may branch off directly from a. iliaca interna) to the walls of the vagina. The uterine artery itself turns upward along the line of attachment of a wide ligament to the uterus. It gives off small branches to the uterine tube, **ramus tubarius**, and to the ovary, **ramus ovaricus** anastomosing with the ovarian artery; a. uterina is spiral in women who have given birth.

6. The **middle rectal artery** (a. rectal is media) originates either from a. iliaca interna or from a. vesicalis inferior branching throughout the walls of the rectum and anastomosing with aa. rectales superior and inferior. This artery also sends branches to the ureter, urinary bladder, prostate, seminal vesicles, and, in females, to the vagina.

7. The **internal pudendal artery** (a. pudenda interna), which in the pelvis gives off only small branches to the nearest muscles and roots of the plexus sacralis, is mainly concerned with supplying blood to the organs situated lower than the diaphragma pelvis and to the region of the perineum. It passes out of the pelvis through the foramen infrapiriforme and then, bending around the posterior side of spina ischiadica, again enters the pelvis through the small ischiatic foramen into the fossa ischiorectalis. Here it divides into branches supplying the lower segment of the rectum in the region of **a. rectalis inferior**, the urethra, the muscles of the perineum and the vagina (in females), Cowper's glands (in males), and the external genitalia (**a. dorsalis penis s. clitoridis, a. profunda penis s. clitoridis**).

The external iliac artery

The **external iliac artery** (a. iliaca externa), beginning at the level of the sacroiliac joint, stretches down and forward along the medial edge of m. psoas to the inguinal ligament; when it passes from under this ligament onto the femur, it is called the femoral artery. Besides small branches to m. psoas, a. iliaca externa gives rise to two large branches, which originate very near the inguinal ligament.

1. The **inferior epigastric artery** (a. epigastrica inferior) passes medially and then upward, between the fascia transversalis in front and the peritoneum parietale in back (the plica umbilicalis lateralis is located in its fold), and enters the sheath of the rectus abdominis muscle. It then leads upward along the posterior surface of the muscle where its branches anastomose with **a. epigastrica superior** (from a. thoracica interna). In its beginning segment it bends around the medial edge of the deep orifice of the inguinal canal, at which point it gives off two branches:

a) **the ramus pubicus** to the symphysis pubica, which anastomoses with a. obturatoria; and

b) a. cremasterica, which leads to m. cremaster and the testis;

2. The **deep circumflex iliac artery** (a. circumflexa ilium profunda), bending around the iliac bone, passes parallel to the inguinal ligament toward the iliac crest posteriorly, supplying m. transversus and the iliac muscle with blood.

Arteries of the lower extremity

The large arteries of the lower extremities, just like the arteries of the upper extremities, were formed gradually; the appearance of a. femoralis on the femur, for instance, was preceded by a. ischiadica, which accompanied the nerve of the same designation and later disappeared. The appearance of a. tibialis anterior and a. tibialis posterior on the crus was preceded by a. peronea. The latter eventually played the role of a collateral vessel of the crus.

The femoral artery

The **femoral artery** (a. femoralis) is a continuation of the trunk of the external iliac artery, so called because it passes under the inguinal ligament through the **lacuna vasorum** near the middle of this ligament. To stop bleeding at the femoral artery, the artery is compressed at the site where it exits onto the femur to the os pubis (superior branch). Medially from the femoral artery is the femoral vein, with which the artery passes to the femoral triangle, proceeding first into the **sulcus iliopectineus** and then into the **sulcus femoralis anterior** and penetrating further through the **canalis adductorius** into the popliteal fossa where it continues in a. poplitea.

The branches of a. femoralis are:

1. The **superficial epigastric artery** (a. epigastrica superficial is) arises near the very beginning of the femoral artery and passes in front of the inguinal ligament under the skin into the region of the navel.

2. The **superficial circumflex iliac artery** (a. circumfiexa ilium supericialis) encircles the iliac bone and proceeds along the inguinal ligament to the skin in the region of spina iliaca anterior superior.

3. The **external pudendal arteries** (aa. pudendae externae), usually two in number (superior et inferior), branch out in the region of the hiatus saphenus and lead medially to the external genitals, to the scrotum or labia majora.

4. The **profunda femoris artery** (a. profunda femoris) is the main vessel through which vascularization of the femur is accomplished. It is a thick trunk, which originates from the posterior side of a. femoralis 4 to 5 cm below the inguinal ligament, lying first behind the femoral artery, then appearing from the lateral side, and, giving off numerous branches, rapidly diminishing in calibre.

The branches of a. profunda femoris:

a) a. **circumflexa femoris medialis**, heading medially and upward, divides into the transverse branch, the **ramus transversus**, which leads to m. pectineus and the adductor muscles of the femur, and a larger, **deep ramus profundus**, which passes between m. iliopsoas and m. pectinous onto the posterior surface of the femur where it branches out on the posterior surface of the adductor muscles, giving off a small, preliminary branch to the hip joint, and anastomoses with a. glutea inferior and a. obturatoria ;

b) a. **circumflexa femoris lateralis branches** off somewhat lower than the previous one; it passes laterally under m. rectus where it divides into the **ramus ascendens** (passing upward and laterally to the greater trochanter, anastomosing with the branches a. circumflexae femoris medialis and a. gluteae inferioris) and the **ramus descendens** (branching into m. quadriceps);

c) **aa. perforantes** (three, terminal branch is 4th) branch off the posterior surface of the deep femoral artery and, perforating the adductor muscles, move to the posterior surface of the femur; the first perforating artery, the largest of the three, supplies the superior artery to the femur (a. diaphyseos femoris superior), while the third supplies the inferior artery (a. diaphyseos femoris inferior); aa. perforantes are significant in ligation of the femoral artery below the effluent branches of the deep femoral artery.

5. The **muscular branches** (rami musculares) of the femoral artery lead to the muscles of the femur.

6. The **descending genicular artery** (a. genu descendens) branches off a. femoralis on its way into the canalis adductorius and, exiting through the anterior wall of this canal with n. saphenus, supplies m. vastus medialis with blood and participates in the formation of the arterial network of the knee joint (rete articulare genu).

The popliteal artery

The **popliteal artery** (a. poplitea) is the direct continuation of the femoral artery. In the popliteal fossa the popliteal artery is situated on the very bone itself (where it can be pressed against the bone when the extremity is half bent) and the posterior surface of the articular bursa to the front and somewhat medially from v. poplitea; still further to the back is the nerve (n. tibialis); further down, the artery lies on the posterior surface of m. poplitei covered by the heads of m. gastrocnemii and then, approaching under the edge of m. solei, separates into two terminal branches (aa. tibiales anterior and posterior).

The branches of a. popliteae:

1. The **superior lateral** and **medial genicular arteries** (aa. genu superiores lateralis and medialis) branch off at the level of the top edge of the condyles of the femur, each curving round the knee joint from its own side. They move on to the anterior surface of the joint where they form an anastomosis and take part in forming the arterial network of the knee joint (rete articulare genu).

2. The **inferior lateral** and **medial genicular arteries** (aa. genu inferiores lateralis and medialis) branch

out in the region of the knee joint as do the superior arteries. The inferior arteries, however, branch away from a. poplitea at the level of the lower edge of the condyles of the femur.

3. The **middle genicular artery** (a. genu media) branches away in the middle between the superior and inferior arteries of the knee joint, perforates the articular bursa, and branches out in cruciate ligaments.

The anterior tibial artery

The **anterior tibial artery** (a. tibialis anterior) is one of two terminal branches of the popliteal artery (the smaller one in calibre). Immediately after it arises, it perforates the deep muscles of the flexor surface of the crus and, through an opening in the interosseous septum, passes into the anterior region of the crus and then between m. tibialis anterior and m. extensor digitorum longus; lower it lies between m. tibialis anterior and m. extensor hallucis longus. It passes superficially over the talocrural articulation covered by skin and fascia; its continuation on the back of the foot is called **a. dorsalis pedis.**

The branches of a. tibialis anterior:

1. The **posterior recurrent branch** of anterior tibial artery (a. recurrens tibialis posterior) branches away while still on the posterior side of the crus, leads upward, and gives off branches to the knee joint and to the joint between the fibula and tibia.

2. The **anterior recurrent branch** of anterior tibial artery (a. recurrens tibialis anterior) arises from the anterior side of the crus leading up to the lateral edge of the kneecap and takes part in forming the rete articulare genu.

3. The **medial** and **lateral anterior malleolar arteries** (aa. malleolares anteriores medialis and lateralis) take part in forming the rete malleolare mediale and laterale.

The posterior tibial artery

The **posterior tibial artery** (a. tibialis posterior) can be regarded as a continuation of the popliteal artery. Descending along the **canalis cruropopliteus**, at the border of the middle one-third of the crus with the inferior it emerges from under the medial edge of m. solei and comes nearer the surface. In the lower one-third of the crus, a. tibialis posterior lies between m. flexor digitorum longus and m. flexor hallucis longus, located medially from the tendon of Achilles, covered here only by skin and the fascial layer. Passing the medial malleolus posteriorly, it divides on the sole into two of its terminal branches: the **lateral and medial plantar arteries** (aa. plantares rnedialis and lateralis). The pulse of a. tibialis posterior is palpated by pressing it against the medial malleolus.

The biggest branch of the posterior tibial artery, the **peroneal artery** (a. peronea/fibularis) originates from a. tibialis posterior in the upper one-third of the latter, passing downward and laterally into the **canalis musculo-peroneus inferior** and ending at the calcaneus (r. calcaneus).

On their way a. tibialis posterior and a. peronea give off branches to the proximate bones, muscles, joints (posterior malleolar branches), and skin.

The arteries of the foot

The **dorsalis pedis artery** (a. dorsalis pedis) passes on the back of the foot. A continuation of the anterior tibial artery, it is situated on the bones in the ligaments with the tendon of the long extensor of the big toe passing medially and the medial belly of the short extensor of the toes passing laterally. Here, on a. dorsalis pedis, one can palpate the pulse by pressing it to the bones. In addition to two or three small branches spreading out in the skin of the dorsal and medial sides of the foot, the dorsal artery of the foot gives off the following branches:

1. the **medial tarsal arteries** (aa. tarseae mediales) to the medial edge of the foot;

2. the **tarsal artery** (a. tarsea lateralis) branches off laterally at the level of the head of the talus, passing to the lateral side. The end of the artery merges with the next branch of the artery of the foot, the arcuate artery;

3. the **arcuate artery** (a. arcuata) branches off opposite the medial sphenoid bone, passes laterally along the bases of the metatarsal bones, and anastomoses with the **lateral tarsal and plantar arteries**. The arcuate artery gives off three arteries anteriorly: **aa. metatarseae dorsales**, the second, third and fourth **metatarsal dorsal arteries**, which pass to the corresponding interosseous metatarsal spaces, each dividing into **two aa. digitales dorsales** to the sides of the fingers facing each other. Each of the metatarsal arteries gives off **anterior**

and **posterior perforating branches**, which pass to the sole of the foot. Often a. arcuata is poorly developed, and a. metatarsea lateralis serves as a substitute. This should be taken into account in checking the pulse on the arteries of the foot in endarteritis;

4. the **first dorsal metatarsal artery** (a. metatarsea dorsalis prima), which is one of two terminal branches of the dorsal artery of the foot, leads to the space between the first and second toes where it divides into two digital branches; prior to the division a branch is given off to the medial side of the big toe;

5. the **deep plantar branch** (ramus plantaris profundus) is the second largest of the terminal branches into which the dorsal artery of the foot divides. It passes through the first metatarsal space to the sole, where it participates in forming the **arcus plantaris**.

There **are two plantar arteries** on the sole of the foot: aa. plantares medialis and lateralis. These are the terminal branches of the posterior tibial artery.

I. The thinner of the two, the medial plantar artery (a. plantaris medialis), is situated in the sulcus plantaris medialis. It terminates at the head of the first metatarsal bone, joining the first plantar metatarsal artery or draining into the arcus plantaris. Along the way it gives off small branches to the adjoining muscles, joints, and skin.

II. The larger lateral plantar artery (a. plantaris lateralis) passes into the sulcus plantaris lateralis medially of the base of the fifth metatarsal bone. There it turns sharply to the middle and, forming a convex arch (**arcus plantaris**) on the bases of the metatarsal bones, terminates laterally of the first metatarsal bone, anastomosing with the ramus plantaris profundus a. dorsal-is pedis. Moreover, it gives off a small branch that joins a. plantaris medialis.

Thus, the arteries of the sole, under constant pressure in standing and walking, form two arches, which, in distinction from the arches of the hand, are situated not in parallel, but in mutually perpendicular planes: in the horizontal plane between aa. plantares medialis and lateralis and in the vertical plane between a. plantaris lateralis and r. plantaris profundus.

The branches of the lateral plantar artery: a) small branches to the adjoining muscles and skin; b) the plantar metatarsal arteries (aa. metatarseae plantares) (four), which, at the posterior end of each of the metatarsal spaces, join the perforating dorsal posterior arteries. At the anterior end, they join the perforating anterior arteries and separate into plantar digital arteries, aa. digitales plantares, which, beginning from the second phalanx, send small branches to the dorsal side of the toes. As a result, on the foot there are two rows of perforating arteries connecting the dorsal vessels with the vessels of the sole. To join aa. metatarseae plantares and aa. metatarseae dorsales, these perforating vessels form anastomoses between a. tibialis anterior and a. tibialis posterior. It may, therefore, be stated that these two main arteries of the crus have two types of anastomoses on the foot in the region of the metatarsus: (1) **arcus plantaris**, and (2) **rami perforantes**.

Distribution of arteries

The structure of the arterial system develops according to the same general laws of structure and development as the organism as a whole and each of its different systems. The arteries supply blood to the various organs according to their structure, function, and development. Therefore, the distribution of arteries in the human body is subject to certain laws, which may be grouped as follows.

Extraorganic arteries

1. The arteries, in accordance with the grouping of the entire body around the nervous system, are situated along the **neural tube and nerves**. Thus, for instance, the arterial trunk—the aorta—and aa. spinales anterior and posterior run parallel to the spinal cord. Segmentary rr. spinales of the respective arteries correspond to each segment of the spinal cord. Moreover, the arteries are initially laid out in close connection with the main nerves. The artery in the upper limb, for example, corresponds to n. medianus and in the lower limb to n. ischiadicus. The arteries continue to run parallel to the nerves and form neurovascular bundles, which also include veins and lymphatic vessels. Interconnections (neurovascular links) existing between nerves and vessels help establish a single neurohumoral regulation.

2. According to the division of the organism into vegetative and animal tubes and into organs of vegetative and animal.life, the arteries divide into **parietal arteries** (leading to the walls of the body cavities) and **visceral arteries** (leading to their contents, that is, to the internal organs), e.g., parietal and visceral branches of the descending aorta.

3. Each extremity receives one **main trunk** for the upper limb, a. subclavia, and one for the lower, a. iliaca externa.

4. The arteries of the trunk retain their segmentary structure: aa. intercostales posteriores, lumbales, rr. spinales, and others.

5. The greatest number of arteries are arranged according to the **principle of bilateral symmetry**: paired arteries of the soma and internal organs. The violation of this principle is connected with the development of arteries within the primary mesenteries.

6. The arteries run parallel to other parts of the vascular system—the veins and the lymphatic vessels—to form a general vascular complex. This complex includes long and thin supplementary arteries and veins, which run parallel to the main ones to create the para-arterial and para-venous bed of the vessels.

7. The arteries are arranged in accordance with the skeleton, which supplies the framework of the organism. The aorta, for instance, runs along the vertebral column, and the intercostal arteries run along the ribs. In the proximal parts of the extremities with one bone (arm, thigh), there is only one main vessel (brachial, femoral arteries); in the medial parts with two bones (forearm, crus), there are two main arteries (radial and ulnar, fibular and tibial); finally, in the distal parts, the hand and foot, which have a radial structure, the arteries correspond to each radial artery of finger or toe.

In the development of the arterial system, the **primary network of vessels** is the first to appear. Conditions for the circulation of blood are more difficult in the peripheral parts of this network than in areas where the organ and the maternal trunk are connected by a shorter route. This is why a certain vessel lying along a straight line between the maternal trunk and the organ is retained, while others fall out of use. As a result:

1. Arteries follow the **shortest distance**, i.e., run in approximately a straight line from the main trunk to the organ. Thus, every artery gives off branches to the organs near it. This explains why the first branches of the aorta, as it arises from the heart, are arteries to the heart itself. This also explains the succession in which the branches separate from the trunk, a succession determined by the place of origin and location of the organs. For example, the first to branch away are arteries from the abdominal aorta to the stomach (from tr. celiacus), then to the small intestine (a. mesenterica superior), and, finally, to the large intestine (a. mesenterica inferior). Another example: arteries branch first to the adrenal gland (a. suprarenalis media) and then to the kidney (a. renalis). The place of origin of the organ is of importance here rather than its ultimate location; thus, a. testicularis branches not from a. femoralis, but from the aorta near which the testicle developed. On the contrary, the scrotum, which originated in the vicinity of the external sex organs, receives arteries at its location, aa. pudendae externae, arising from the nearest large trunk, a. femoralis. If one keep in mind the law of the shortest distance and the general laws of development, it is always possible to determine the organs to which a given artery will extend branches.

2. The arteries are situated on the **flexor surfaces** of the body since the vascular tube stretches and collapses in extension. This explains the location of the common carotid artery on the anterior surface of the neck and the location of the major arteries of the hands on the palm. On the lower extremity the flexor surface is located near the hip joint in the front and near the knee joint in the back; the femoral artery, therefore, turns spirally from the anterior surface of the thigh to the posterior surface.

3. The arteries are situated in **protected grooves** and canals formed by bones, muscles, and fasciae, which protect the vessels from compression and injury. Since the dorsal side of the bodies of four-legged animals is unprotected, in the process of evolution the vessels became located on the ventral side. This position was preserved in human beings, which explains the position of the aorta and its branches in front of the spine and of the arteries of the neck and extremities mainly on the anterior surface of the body. There are no large arteries on the back.

4. The arteries **enter the organ on the concave**, medial or internal surface facing the source of nutrition. Thus, all the hila of the internal organs are on the concave surface facing the medial line where the aorta that sends them branches is positioned.

5. The arteries adapt according to the function of the organ:

a) **vascular networks**, **rings**, and arch-shaped **anastomoses** are found in organs connected with locomotion. The branches of large arteries passing near joints form an articular network, rete articulare, which allows the blood to flow freely to the joint, even when the vessels are compressed or stretched during movement. Mobile inner organs such as the stomach and intestine, which change in size and form, have many ring-shaped and arch-shaped anastomoses;

b) the **calibre of the arteries** is determined not only by the size but also the function of the organ. Since the kidney, for example, demands a great influx (a quater) of blood to secrete urine, the renal artery, which supplies the kidney, is no smaller in diameter than the mesenteric artery, which supplies the long intestine. The arteries of the thyroid gland are larger than the arteries of the larynx since the former produces hormones, which requires far more blood than needed to supply the larynx;

c) in connection with this the **endocrine glands** receive nutrition from **multiple sources**. The thyroid gland, for instance, gets blood from all proximate large carotid and subclavian arteries (both sides) and from the aorta; the adrenal gland receives blood from a. phrenica inferior (a. suprarenalis superior), from the aorta (a. suprarenalis media), and from the renal artery (a. suprarenalis inferior).

Various patterns in the branches of the intraorganic arteries

The contents of any organ include the vascular system, which is part of the organ as a whole. The character of the intraorganic arterial bed and the architectonics of the intraorganic arteries correspond, therefore, to the structure, function, and development of the organ in which these vessels branch out. This explains why the arterial bed is built differently in organs of different structure and similarly in organs of similar structure.

Intraosseous arteries

Long tubular bones, in accordance with their structure, function, and development, receive **diaphyseal arteries**; the main artery (**a. nutritia** or, to be more precise, a. diaphyseos princeps) enters the medial section of the diaphysis and divides into **r. proximalis** and **r. distalis**; accessory arteries (**aa. diaphyseos accessoriae**) penetrate the bone at the ends of the diaphyses. Diaphyseal arteries supply the diaphysis with blood from within, while the **cortical layer** receives cortical **arteries from the periosteum**. The existence of two systems of diaphyseal arteries explains why one layer of the diaphysis may be affected with a purulent process while the other remains intact.

Apart from diaphyseal arteries, the long tubular bone is also supplied by arteries which are part of metaphyses (**metaphysial arteries**), epiphyses (**epiphysial arteries**), and apophyses (**apophysial arteries**). The metaepiphysial cartilage first separates the vessels of the epiphysis from the vessels of the metaphysis. Once synostosis has occurred, all the vessels join to form a single system supplying the given bone.

In **short tubular bones** possessing **one epiphysis** (**monoepiphiysar**) (metacarpus, metatarsus and phalanges), there is a single system of epiphyseal arteries. In **short spongy bones** (vertebra, carpus, tarsus, sternum), the vessels enter from different sides on their way to sites of ossification.

The **arteries of the ligaments** run along the bundles of connective tissue and, together with them, arrange themselves perpendicular to the corresponding axis of rotation.

The **arteries of the muscles** proceed first along the functional axis of the muscle and then penetrate the perimysium internum. Within it the arteries run parallel to the bundles of muscle fibres and send them perpendicular branches, thus forming loops which stretch the length of the muscle bundles.

In **lobate organs** (lungs, liver, kidneys), the arteries enter the centre of the organ and spread out (in 3-D mode) to the periphery corresponding to the lobes and lobules of the given organ.

In **tubular organs** the vessels are arranged as follows:

1. Parallel to the long axis of the tube and along one of its sides runs an artery from which transverse branches arise at right angles. These branches encircle the tube (for example, the intestine, uterus, fallopian tubes).
2. The vessels run parallel to the long axis along one side of the tube and give off branches which are mainly longitudinal (the ureter, for example).

The arteries of the **brain** also pass from the periphery to the centre. In the **cerebral cortex** (screening centres), they appear as straight short arteries, while in the **white matter** they are long and straight, passing along the nerve bundles. In the **subcortical nuclei** (nuclear centres), they form vascular networks.

The **spinal cord** is thus supplied with blood by segmentary arteries (a vertebralis, aa. intercostales posteriors, aa. lumbales, aa. sacralis mediana et sacrales laterales). On the surface the vessels form a network of arteries which lead, along radii from the periphery to the center, into the thick wall of the cord. The lumbar artery give rise for spinal cord the great anterior segmental medullary artery of Adamkievwicz, usually arise via a spinal branch from upper lumbar artery and enters the vertebral canal through the intervertebral foramen at the same level.

In the **nerve roots** and **in the nerves** themselves, the arteries run in streaks of endoneurium parallel to the bundles of nerve fibers. The arteries send perpendicular branches to the nerve fibers, just as they do to the muscles, which form longitudinal loops stretching along the nerve bundles.

Thus, the arteries are similar in all fibrous organs (muscles, tendons, nerves); they enter at several places along the length of the organ and lie parallel to the fibres. Blood is supplied not only by the arteries entering the organ directly, but also by neighbouring arteries, which supply blood through **anastomoses**. All the arteries of a given organ and the formations surrounding it constitute the system of vessels of the organ.

Collateral blood circulation

The plasticity of the blood vessels and the continuous blood supply to the organs and tissues is ensured by the system of collateral blood circulation, an important functional adaptation of the organism.

Collateral blood circulation occurs in physiological conditions when the flow of blood is temporarily obstructed by the compression of the blood vessels (for instance, in the joints). It may take place under pathological conditions: occlusion, injury, or ligation of the vessels. Under physiological conditions the blood is channelled through side vessels called **collateral vessels** (a. collateralis ulnaris, for example), running parallel to the main vessels. The blood flow is consequently called **collateral blood circulation.** When the blood flow along the main vessels is impeded for some reason, the blood passes through anastomoses to the nearest side branches which dilate, twist, and gradually transform into collaterals. Thus, collaterals exist under normal conditions and can develop in the presence of anastomoses. Consequently, if normal circulation in a vessel is disturbed by an obstacle in the path of the blood, existing collateral blood vessels are first put to use and then new bypasses are developed. As a result, disturbed circulation is restored. A major role in this process is played by the nervous system.

An understanding of collateral blood circulation requires strong knowledge of the anastomoses which link the various vascular systems along which collateral blood flow can be established in case of injury, ligation during surgery, or occlusion (thrombosis and embolism).

*Anastomoses between branches of the major arteries (aorta, carotid arteries, subclavian and iliac arteries, and others) that function as independent vascular systems are called **intersystemic anastomoses**.

*Anastomoses between branches of a single, large arterial trunk within the limits of the artery are called **intrasystemic anastomoses**.

These anastomoses were already noted in the discussion of arteries above. Collateral circulation also involves thin arteries and veins attending major vessels in neurovascular bundles. These thin vessels comprise the perivascular and perineural arterial and venous bed.

Apart from their practical significance, the anastomoses provide evidence of the unity of the arterial system, which we have arbitrarily divided for convenience.

The veins of systemic circulation the system of vena cava superior

The **superior vena cava** (vena cava superior) is a thick (about 2.5 cm) but short (5-6 cm) trunk located to the right and somewhat posteriorly of the ascending aorta. It is formed by the **union** of the **right** and **left innominate veins** (vv. brachiocephalicae dextra and sinistra) behind the junction of the first right rib with the sternum. From there it passes downward along the right edge of the sternum, posteriorly of the first and second intercostal spaces; at the level of the top edge of the third rib, concealed behind the right auricle of the heart, it drains into the right atrium. Its posterior wall touches a. pulmonalis dextra, which separates it from the right bronchus. It also adheres to the right superior pulmonary vein for a very short distance at the place where it drains into the atrium; both these vessels cross it transversely. **V. azygos**, bending over the root of the right lung (the aorta bends over the root of the left lung) at the level of the upper edge of the right pulmonary vein, **drains** into the **vena cava superior**. The anterior wall of the vena cava superior is separated from the anterior wall of the thorax by a fairly thick tissue of the rigt lung.

The innominate veins

The **right** and **left innominate veins** (vv. brachiocephalicae dextra and sinistra), which form the vena cava superior, are, in their turn, each formed by the fusion of the subclavian and internal jugular veins (v. subclavia and v. jugularis interna).

The **right innominate vein**, just 2-3 cm in length, is shorter than the left. Originating behind the right sternoclavicular joint, it runs obliquely downward and medially to the place where it joins the contralateral vein on the left. In front the right innominate vein is covered by mm. sternocleidomastoideus, sternohyoideus, and sternothyreoideus and lower by the cartilage of the first rib.

The **left innominate vein** is about twice the length of the right. It originates behind the left sternoclavicular joint and passes behind the manubrium sterni, separated from it only by adipose tissue and the thymus. From there, it leads to the right and downward where it joins the right innominate vein, with its lower wall closely adhering meanwhile to the convexity of the aortic arch; in front it crosses the left subclavian artery, the upper sections of the left common carotid artery, and the innominate artery. **Vv. thyreoideae inferiores** and **v. thyreoidea ima**, originating from the dense venous plexus at the lower edge of the thyroid gland, and the veins of the thymus drain into the innominate veins.

The internal jugular vein

The **internal jugular vein** (v. jugularis interna) carries blood from the cavity of the skull and the organs of the neck. Beginning at the foramen jugulare, where it forms a distention (the **bulbus superior** venae jugularis internae), the vein passes downward, laterally of a. carotis interna and, further down, laterally of a. carotis communis. A second distention (the **bulbus inferior** v. jugularis internae) is formed at the lower end of v. jugularis internae before it joins v. subclavia; there are **one or two valves** in the vein in the region of the neck above this distention. In the back region the internal jugular vein is covered by mm. sternocleidomastoideus and omohyoideus.

The veins of the dura mater, usually in twos, stretch in attendance to the corresponding arteries and drain partly into the sinuses and partly into the pterygoid plexus.

Besides its own veins, the dura mater contains several reservoirs collecting blood from the brain; these are the **sinuses of the dura mater** (sinus durae matris).

The **sinuses are venous canals** (triangular on transverse section) devoid of valves and located in the thickness of the dura mater at the attachment of its processes to the skull; they differ from veins in the structure of their walls which are composed of tightly stretched layers of the dura mater and consequently do not collapse when cut and gape on being injured. The inflexibility of the walls of the venous sinuses provides free drainage of venous blood in changes of intracranial pressure; this is important for uninterrupted activity of the brain, which explains why such venous sinuses are present only in the skull.

The veins of brain

The veins of the brain possess no valves, and their walls, owing to the absence of muscular tissue, are extremely thin. They pierce the arachnoid membrane and the inner or meningeal layer of the dura mater, and open into the cranial venous sinuses. They may be divided into two sets, **cerebral** and **cerebellar.**

The **cerebral veins** (vv. cerebri) are divisible into **external** and **internal** groups according as they drain the outer surfaces or the inner parts of the hemispheres.

The **external veins** are the **superior** (vv. cerebri superiors), **inferior** (vv. cerebri inferiors), and **middle** cerebral (v. cerebri media; superficial Sylvian vein). The **basal vein: anterior cerebral vein, deep middle cerebral vein** deep Sylvian vein **and inferior striate veins.**

The **internal cerebral veins** (vv. cerebri internæ; veins of Galen; deep cerebral veins) drain the deep parts of the hemisphere and are two in number; the **terminal** and **choroid veins.**

Beneath the splenium of the corpus callosum, where they unite to form a short trunk, the **great cerebral vein** (v. cerebri magna [Galeni]; great vein of Galen).

The **cerebellar veins** are placed on the surface of the cerebellum, and are disposed in two sets, **superior** and **inferior**.

The cranial venous sinuses

The sinuses are as follows.

The **transverse sinus** (sinus transversus), the largest and widest sinus which runs along the posterior margin of the tentorium cerebelli in the sulcus sinus transversi of the occipital bone. From here it descends into the sulcus sinus sigmoidei under the name of the **sigmoid sinus** (sinus sigmoideus), and at the jugular foramen is continuous with the orifice of the **internal jugular vein**. As a result, the transverse and sigmoid sinuses form the main receptacle for all the venous blood of the cranial cavity. All the other sinuses drain into it either directly or indirectly.

The following sinuses drain directly into it.

The **superior sagittal sinus** (sinus sagittalis superior) runs on the upper margin of falx cerebri for the whole length of sulcus sinus sagittalis superioris from crista galli to the internal occipital protuberance (on either side of the superior sagittal sinus, within the dura mater, are located the so-called blood lacunae which are small cavities communicating with the sinus and the diploic veins on the one side and with the veins of the dura mater and brain on the other).

The **occipital sinus** (sinus occipitalis) is a continuation, as it were, of the superior sagittal sinus along the attachment of falx cerebelli to the internal occipital crest and then (after bifurcating) along both margins of the foramen magnum of the occipital bone.

The **straight sinus** (sinus rectus) runs on the line of attachment of falx cerebri to tentorium cerebelli. It receives anteriorly the **inferior sagittal sinus** (sinus sagittalis inferior) stretching on the free lower margin of fair cerebri and **vena cerebri magna** (Galeni) carrying blood from the deep parts of the brain.

At the **confluence of these sinuses** (transverse, superior sagittal, straight, and occipital) a common expansion forms; it is called the confluence of the sinuses (**confluens sinuum**), or torcular Herophili.

The **cavernous sinus** (sinus cavernosus) is located on the base of the skull lateral to the sella turcica. It has the apperance of either a venous plexus or a wide lacuna surrounding the internal carotid artery. It is connected with a similar sinus on the other side by means of two transverse communications, **intercavernous sinuses** (sinus intercavernosus), passing in front of and behind the hypophyseal fossa as a consequence of which a venous circle forms in the region of the sella turcica.

According to certain data, the cavernous sinus is an intricate anatomical complex whose components, in addition to the sinus itself, are the internal carotid artery, the nerves and the connective tissue surrounding them. All these structures compose, as it were, a special instrument which plays an important role in regulation of the intracranial flow of venous blood. The cavernous sinus receives anteriorly the **superior ophthalmic vein** passing through the superior orbital fissure, as well as the inferior end of the **spheno-parietal sinus** (sinus sphenoparietalis) running on the margin of the ala minor of sphenoid bone. The cavernous sinus is drained of blood by two sinuses located behind it; namely the **inferior** and **superior petrosal sinuses** (sinus petrosus superior and inferior) located in the superior and inferior petrosal sulci. Both inferior petrosal sinuses communicate by means of several venous canals which lie within the dura mater on the basal part of the occipital bone and are united under the term plexus basilaris. This plexus is connected with the venous plexuses of the vertebral canal, into which blood from the cranial cavity flows.

Blood drains from the sinuses mainly into the internal jugular veins, but the sinuses are also connected with the veins of the outer surface of the skull through **emissary veins** (venae emissariae) transmitted through openings in the skull bones (foramen parietale, foramen mastoideum, canalis condylaris). Small veins leaving the skull together with nerves through foramen ovale, foramen rotundum and canalis hypoglossi play a similar role. The **diploic veins** and the veins of the spongy substance of the cranial bones also drain into the sinuses of the dura mater, while their other end may be connected with the veins on the external surface of the head. The diploic veins (venae diploicae) are canals anastomosing with one another and lined by a layer of endothelium; they pass in the spongy substance of the flat cranial bones. The diploic veins are: **frontal, anterior temporal, posterior temporal** and **occipital.**

The orbital cavity is drained into the sinus cavernosus by **vv. ophthalmicae superior** and v. ophthalmica inferior, which joins the plexus pterygoideus.

The following veins flow into v. **jugularis interna**:

1. **The facial vein** (v. facialis) passes under m. stylohyoideus and m. sternocleidomastoideus. (it drains sometimes into v. jugularis ext.) The veins draining into the facial vein correspond to the branches arising from the facial artery.

2. The **retromandibular vein** (v. retromandibularis) collects blood from the temporal region. Further down, a trunk carrying blood out of the **plexus pterygoideus** (a dense plexus between mm. pterygoidei correspond to maxillar artery) drains into v. retromandibularis after which the vein, passing through the thickness of the parotid gland with the external carotid artery, merges with v. facialis below the angle of the lower maxilla.

The shortest route connecting v. facialis with the pterygoid venous plexus is the "anastomotic vein" (v. anastomotica facialis) situated at the level of the alveolar margin of the lower maxilla. Since it connects the **superficial and deep veins** of the face, the anastomotic vein may spread infection, which may be of importance in practice.

3. The **pharyngeal veins** (vv. pharyngeae) form a plexus on the pharynx and flow either directly into v. jugularis interne or empty into v. facialis.

4. The **lingual vein** (v. lingualis) acoompanies the artery of the same name.

5. The **superior thyroid veins** (vv. thyreoideae superiores) collect blood from the upper parts of the thyroid gland and the larynx.

6. The **middle thyroid vein** (v. thyreoidea media) (more exactly, lateral-is) arises from the lateral edge of the thyroid gland and drains into v. jugularis interne. At the lower margin of the thyroid gland, there is an unpaired venous plexus, **plexus thyreoideus** impar, which drains through vv. thyreoideae superiores into v. jugularis interne and also through vv. thyreoideae inferiores and v. thyreoidea ima into the veins of the middle mediastinum.

The external jugular vein

The **external jugular vein** (v. jugularis externs) originates behind the floor of the auricle and emerges at the level of the maxilla angle, from the region behind the mandibular fossa. From there it descends into the subcutaneous tissue covered by m. platysma and travels along the external surface of the sternocleidomastoid muscle, crossing it obliquely downward and posteriorly. On reaching the posterior edge of the sternocleidomastoid muscle, the vein enters the supraclavicular region where it immediately descends and drains into the subclavian vein, usually in a common trunk with **v. jugularis anterior**. Behind the floor of the auricle**, v. auricularis posterior** and **v. occipitalis** drain into v. jugularis externa.

The anterior jugular vein

The **anterior jugular vein** (v. jugularis anterior) varies greatly in size and form. It is made up of small branches located over the hyoid bone, from which point it descends. Both the right and left anterior jugular veins perforate the deep fascia colli propriae, enter the spatium interaponeuroticum suprasternale, and drain into the subclavian vein. In the suprasternal space the anterior jugular veins anastomose, with either one or two trunks. Thus a **venous arch**, arcus venosus juguli, is formed over the top edge of the sternum and the clavicles. In some cases the right and left veins are replaced by a single unpaired vein, v. jugularis anterior, which descends along the median line and drains below into the venous arch formed, in such instances, by an anastomosis between vv. jugulares externae.

The subclavian vein

The **subclavian vein** (v. subclavia) is a direct continuation of v. axillaris. It is located below and to the front of the subclavian artery, from which it is separated by m. scalenus anterior; behind the sternoclavicular joint the subclavian vein merges with v. jugularis interna. The merger creates v. brachiocephalica.

The veins of the upper extremity

The veins of the upper extremity are divided into **deep** and **superficial veins**.

The **superficial or subcutaneous veins** anastomose to form a widely looped network which in places has larger trunks. These trunks are the following:

1. The **cephalic vein** (v. cephalica) arises from the radial side of the **dorsal rete of the hand**. Along the radial side of the forearm, it reaches the elbow where it anastomoses with the basilic vein and then ascends along the **sulcus bicipitalis lateralis** up to the trigonum deltoideo-pectorale where it perforates the fascia and drains into **v. axillaris**.

2. The **basilic vein** (v. basilica) originates on the ulnar side of the dorsal rete of the hand and passes to the medial segment of the anterior surface of the forearm along m. flexor carpi ulnaris to the ulnar flection. There it anastomoses with v. cephalica through **v. mediana cubiti**. After it continues in the **sulcus bicipitalis medialis**, perforates the fascia in the middle of the arm, and drains into one of vv. brachiales.

3. The **median cubital vein** (v. mediana cubiti) is an obliquely positioned anastomosis connecting v. basilica and v. cephalica in the region of the elbow. It usually receives blood from v. mediana antebrachii carried from the palmar side of the hand and forearm. The median cubital vein is important in medical practice as the site of intravenous injections and blood collecting.

Deep veins attend arteries of the same name, usually two veins for every artery. Thus, there are two brachial, two ulnar, two radial, two interosseal veins and two both palmar arches.

Both brachial veins join at the lower edge of m. pectoralis major to form the **axillary vein** (v. axillaris), which passes medially and anteriorly of the artery of the same name in the axillary fossa, covering it partially. Passing under the clavicle, it continues further as v. subclavia. Besides v. cephalica, acromiothoracic vein (v. thoracoacromialis) (corresponding to a.thoracoacromialis), lateral thoracic vein (v. thoracica lateralis) (into which v. thoracoepigastrica, a large trunk of the abdominal wall, often drains), subscapular vein (v. subscapularis), and humeral circumflex veins (vv. circumflexae humeri) also flow into v. axillaris.

Vena azygos and vena hemiazygos

Vena azygos (v. azygos) and **vena hemiazygos** (v. hemiazygos) form in the abdominal cavity out of ascending lumbar veins which connect the lumbar veins longitudinally. They pass upward behind m. psoas major and make their way into the thoracic cavity between the muscular bundles of the diaphragm's crus: v. azygos together with the right n. splanchnicus, v. hemiazygos with the left n. splanchnicus or the sympathetic trunk.

In the thoracic cavity **v. azygos** rises along the right lateral side of the spinal column, closely adhering to the posterior wall of the oesophagus. At the level of the fourth or the fifth vertebra, it departs from the spine and, bending over the root of the right lung, drains into the vena cava superior. Besides the branches carrying blood from the **organs of the mediastinum**, nine right **inferior intercostal veins** and, through them, the **veins of vertebral plexuses** also drain into the unpaired vein. Near the place where the unpaired vein bends over the root of the right lung, it receives blood from the v. intercostalis superior dextra created by the merger of three right superior intercostal veins.

V. hemiazygos lies on the left lateral surface of the vertebral bodies behind the descending thoracic aorta. It ascends only up to the seventh or eighth thoracic vertebra, then turns right and, passing obliquely upward over the anterior surface of the vertebral column **behind the thoracic aorta and ductus thoracicus, drains into v. azygos**. It receives branches from the **organs of the mediastinum** (esophagus) and the **lower left intercostal veins**, as well as veins of the **vertebral plexuses**. The upper left intercostal veins drain into v. hemiazygos accessories, which runs from top to bottom, arranging itself, just as v. hemiazygos, on the left lateral surface of the vertebral bodies, and drains either into v. hemiazygos or directly into v. azygos, bending to the right over the anterior surface of the seventh thoracic vertebral body.

The parietal veins of the trunk

The **posterior intercostal veins** (vv. intercostales posteriores) accompany arteries of the same name in the intercostal spaces. One vein accompanies every artery. It has already been mentioned that the intercostal veins drain into the azygos and hemiazygos veins. **Ramus dorsalis** (the branch carrying blood from the deep dorsal muscles) and **ramus spinalis** (from the veins of the vertebral plexuses) drain into the posterior ends of the intercostal veins near the spinal column.

The **internal thoracic vein** (v. thoracica interna) accompanies the artery of the same name; it is binary the greater part of its length, but near the first rib both veins merge into a single trunk, which drains into v. brachiocephalica of the same side.

The upper segment of the internal thoracic vein, **v. epigastrica superior**, anastomoses with v. **epigastrica inferior**, which empties into v. iliaca interna, as well as with the subcutaneous veins of the abdomen (vv. subcutaneae abdominis), forming a large looped network in the subcutaneous tissue. From this rete the blood flows upward through **v. thoracoepigastrica** and **v. thoracica lateralis** into v. axillaris. The blood flowing downward runs through v. epigastrica superficialis and v. circumflexa ilium superficialis into the femoral vein. Thus, the **veins in the anterior abdominal wall join the areas of ramification of the venae cavae superior and inferior (cava-caval anastomose)**. In addition, several small venous branches in the region of the umbilicus are joined by **vv. para-umbilicales** with the system of **the portal vein** (**porto-caval anastomose**).

Vertebral venous plexuses

There are four **venous vertebral plexuses**: **two internal** and **two external**. The internal vertebral plexuses (plexus venosi vertebrales interni) **anterior** and **posterior** are located in the vertebral canal and consist of venous rings, one for every vertebra. The **veins of the spinal** cord drain nto the internal vertebral plexuses as do **vv. basivertebrales**, which arise from the posterior surfaces of the vertebral bodies and carry blood from the spongy substance of the vertebrae. The **external vertebral plexuses** (plexus vertebrales externi) are, in turn, subdivided into: the **anterior plexus** on the anterior surface of the vertebral bodies (developed mainly in the cervical and sacral regions) and the **posterior plexus** resting on the arches of the vertebrae, covered by deep dorsal and cervical muscles. Blood from the vertebral plexuses is drained in the torso through **vv. intervertebrales** into **vv.intercostales posteriores** and **vv. lumbales**. Blood in the neck drains mainly into **v. vertebralis**, which flows with the vertebral artery into v. brachiocephalica independently or after it has joined v. cervicalis profunda (system of superior vena cava).

The system of vena cava inferior

The **inferior vena cava** (v. cava inferior), the thickest venous trunk in the body, lies in the abdominal cavity close to the right side of the aorta. It is formed at the level of the **fourth lumbar** vertebra by the merger of **two common iliac** veins slightly below the division of the aorta and immediately to the right of it. The vena cava inferior passes upward and somewhat to the right so that the higher it rises, the further it is from the aorta. The lower segment of the vein adjoins the medial edge of the right psoas muscle and then passes onto its anterior surface; its upper segment rests on the lumbar part of the diaphragm. Lying in the **sulcus venae cavae** on the posterior surface of the liver, the inferior vena cava then passes through the **foramen venae cavae** of the diaphragm into the thoracic cavity and immediately drains into the **right atrium**.

The veins draining directly into the vena cava inferior correspond to the paired branches of the aorta (except vv. hepaticae). They are divided into **parietal** and **visceral veins**.

The **parietal veins**: (1) the **right** and **left lumbar veins** (vv. lumbales dextrae and sinistrae), four veins on each side corresponding to arteries of the same name receive anastomoses from the vertebral plexus; they join by longitudinal trunks, **vv. lumbales ascendens**; (2) the **inferior phrenic** veins (vv. phrenicae inferiores) drain into the inferior vena cava where it passes in the sulcus of the liver.

The **visceral veins**: (1) the **testicular (ovarian) veins** (vv. testiculares (ovarica)) originate in the region of the testes (ovaries) and form plexuses with arteries of the same name (plexus pampiniformis). The right v. testicularis empties directly into the vena cava inferior at an acute angle; the left empties into the left renal vein at a right angle. This right angle slows down the flow of blood and causes the more frequent occurrence of valicocele in the left spermatic cord as compared to the right (in females v. ovarica begins in the hilum of the ovary); (2) the **renal veins** (vv. renales) pass in front of the renal arteries practically covering the latter completely; the left renal vein is longer than the right and runs ahead of the aorta, venous blood drains from the cortex first into the stellate veins (venulae stellatae), then into the interlobular veins accompanying the interlobular arteries, and then into the arcuate veins. Venous blood from the medulla flows in the venulae rectae. The large venous tributaries unite to form the renal vein; (3) the **right suprarenal vein** (v. suprarenalis dextra) drains into the inferior vena cava immediately above the renal vein; **v. suprarenalis sinistra** usually fails to reach the vena cava and drains into the renal vein in front of the aorta; (4) the **hepatic veins** (vv. hepaticae) empty into the vena cava inferior as it passes over the posterior surface of the liver; the hepatic veins carry blood from the liver, which receive it through **the portal vein and hepatic artery**.

The portal vein

The **portal vein** (v. portae) collects blood from all unpaired organs of the abdominal cavity with the exception of the liver. Blood carrying nutrients absorbed in the gastrointestinal tract is carried by the portal vein to the liver where the nutrients are used, poisons are neutralized, and glycogen is deposited. Blood from the pancreas, which supplies insulin for the regulation of sugar metabolism, and from the spleen, which yields the products of disintegration of blood (red blood cells) elements used by the liver to evacuate by bile, is also carried by the portal vein. The structural ties between the portal vein and the gastrointestinal tract and its large glands (liver and pancreas) are both functional and genetic. The portal vein is a thick venous trunk located in **lig. hepatoduodenale** with the **hepatic artery** and **ductus choledochus**.

The portal vein forms behind the head of the pancreas out of the **splenic vein** (v. lienalis) and two **mesenteric veins** (vv. mesentericae), **superior (usually) and inferior**. On its way to the hepatic porta in the peritoneal ligament already mentioned, the portal vein receives **vv. gastricae sinistra** and **dextra** and **v. prepylorica** and divides in the porta hepatis into **two branches** (**dexter** and **sinister**), which pass into the parenchyma of the liver where they spread into a multitude of small branches which entwine the hepatic lobules (**vv. interlobulares**), after fusion with **aa.interlobulares** formate numerous capillaries of hepatic lobule (morpho-functional unit) penetrate the lobules and eventually join in **vv. centrales**, which merge in the **hepatic veins** draining into the **inferior vena cava**.

Thus, in distinction from other veins, the **system of the portal** vein fits between **two networks of capillaries**: the first capillary network provides a source for the venous trunks that comprise the portal vein, while the second network runs throughout the liver, where the portal vein splits into its terminal branches.

The splenic vein

The **splenic vein** (v. lienalis) carries blood from the spleen, the stomach through **v. gastro-epiploica sinistra** and **vv. gastricae breves**, and the pancreas, along the upper edge of which it passes posteriorly and below the splenic artery to v. portae.

The mesenteric veins

The **superior** and **inferior mesenteric veins** (vv. mesentericae superior and inferior) correspond to the arteries of the same name. The **superior mesenteric vein** drains venous branches from the small intestine (**vv. in-lestinales**), the caecum, the ascending colon, and the transverse colon (**v. colia dextra** and **v. colica media**) and, passing behind the head of the pancreas, joins the lower mesenteric vein. The **inferior mesenteric vein** originates from the venous plexus of the rectum, the **plexus venosus rectalis** (hemorrhoidalis). Passing upward from this plexus, the vein receives branches from the sigmoid colon (**vv. sigmoideae**), the descending colon (**v. colica sinistra**), and from the left half of the transverse colon. V. mesenterica inferior then merges with the v. mesenterica superior behind the head of the pancreas either jointly with the splenic vein or independently.

The common iliac veins

The **right** and **left common iliac veins** (vv. iliacae communes) join at the level of the lower edge of the fourth lumbar vertebra to form the vena cava inferior. The right common iliac vein is located behind the iliac artery; the left vein lies below and behind the artery of the same name. The left vein, then, turns medially and passes behind the right common iliac artery to merge with the right common iliac vein to the right of the aorta. Each common iliac vein at the level of the sacroiliac joint comprises, in its turn, two veins: **external** and **internal iliac veins**.

The internal iliac vein

The **internal iliac vein** (v. iliaca interns) is a short but thick trunk located behind the internal iliac artery. The veins that make up the internal iliac vein correspond to arterial branches of the same name. Normally, these veins are double outside the pelvis but merge into a single trunk on entering it. A number of venous plexuses, which anastomose with one another, are formed among the branches of the internal iliac vein.

1. The **anterior sacral venous plexus** (plexus venosus sacralis) consists of sacral veins, lateral and median.

2. The **rectal venous plexus** (plexus venosus rectalis s. hemorrhoidalis [BNA]) is a plexus in the walls of the rectum. Three plexuses can be distinguished: **submucous, subfascial,** and **subcutaneous**. The **submucous** or **internal venous plexus** (plexus rectalis internus), in the region of the lower ends of the columnae rectalis consists of several venous nodules arranged in the shape of a ring. The abducent veins of this plexus perforate the muscular coat of the intestine and merge with the veins of the **subfascial or external plexus** (plexus rectalis externus). V. rectalis superior and vv. rectales mediae arise from the latter, accompanying arteries of the same name. V. rectalis superior drains through the inferior mesenteric vein into the **portal vein system**, while vv. rectales mediae empty into the system of the **vena cava inferior** through the internal iliac vein. A **third (subcutaneous) plexus** forms in the region of the external sphincter of the anus, plexus subcutaneus ani, which make up **vv. rectales inferiores** draining into **v. pudenda interna** (internal iliac vein, system of vena cava inferior).

3. The **vesical venous plexus** (plexus venosus vesicalis) is located in the region of the fundus of the urinary bladder; the blood from this plexus is drained into the internal iliac vein through **vv. vesicales**.

4. The **prostatic venous plexus** (plexus venosus prostaticus) is situated between the urinary bladder and the pubic adhesion, encompassing the prostate and the seminal vesicles in males. The unpaired **v. dorsalis penis** drains into the plexus venosus prostaticus. **V. dorsalis clitoridis** in females corresponds v. dorsalis penis in males.

5. The **uterine venous plexus** (plexus venosus uterinus) and the **vaginal venous plexus** (plexus venosus vaginalis) in females are located in the wide ligaments along the sides of the uterus and further downward along the lateral walls of the vagina. The blood from them drains mainly through v. uterina into the internal iliac vein,

although part is also drained through the ovarian vein (plexus pampiniformis).

Porto-caval anastomoses

The roots of the **portal vein** anastomose with the roots of veins from the systems of the superior **vena cava and inferior vena cava**, forming so-called **porto-caval anastomoses**, which are of practical significance.

Visceral:

1. On the top, in the pars abdominalis of **the oesophagus** between the roots of v. gastrica sinistra, which empties into the portal vein, and vv. esophageae, which drain into vv. azygos and hemiazygos and further into v. cava superior.

2. On the bottom, in the lower part of **the rectum** between v. rectalis superior, which drains through v. mesenterica inferior into the portal vein, and vv. rectales media (flowing into v. iliaca interna) and inferior (flowing into v. pudenda interna), which together drain into v. iliaca interna and further into v. iliaca communis from the system of the vena cava inferior.

Parietal:

1. In the front, in the region of the navel (umbilicus) where the branches of **vv. para-umbilicales** (passing through the thickness of **lig. teres hepatis** to the portal vein), **v. epigastrica superior** from the system of the **vena cava superior** (v. thoracica interna, v. brachiocephalica), and

2. **v. epigastrica inferior** from the system of the **vena cava inferior** (v. iliaca externa, v. iliaca communis) anastomose.

Portocaval anastomoses, thus, provide a bypass for the rainage of blood when obstacles appear in the liver (e.g., in cirrhosis), in the head of pancreas (e.g., tumor). In such cases the veins around the navel dilate and acquire a typical appearance known as **Medusa's head** (Medusa Gorgona – greek mythological personage, which had snakes instead of head hair).

In the back, in the lumbar region between the roots of the veins of the mesoperitoneal segments of the large intestine (from the system of the portal vein) and the parietal vv. lumbales (from the system of the vena cava inferior). All these anastomoses form what is known as the Retzius system.

Cava-caval anastomosis

1. There is, in addition, a **cava-caval anastomosis** on the posterior abdominal wall among the roots of **vv. lumbales** (from the system of the **vena cava inferior**). These roots are connected with the paired v. **lumbalis ascenders**, which is the origin of **v. azygos** (to the right) and **v.hemiazygos** (to the left) (from the system of the **vena cava superior**).

2. Between **vv. lumbales** (tributaries of inferior vena cava) and the intervertebral veins (plexus vertebrales external and internal), which in the neck and thoracic regions serve as roots of the **vena cava superior** (by **v. azygos** (to the right) and **v.hemiazygos** (to the left) and **vertebral vein**, or cervicalis profunda).

3. Anterior wall of trunk possesss **v. epigastrica superior** from the system of the **vena cava superior** (v. thoracica interna, v. brachiocephalica), **v. thoracica lateralis** (v.axillaris, v. subclavia), and. **vv. epigastrica inferior, superficialis** from the system of the **vena cava inferior** (v. iliaca externa, v. iliaca communis) that anastomose in subcutaneous region.

The external iliac vein

The **external iliac vein** (v. iliaca externa) is the direct continuation of v. femoralis, which, after passing under the inguinal ligament (**lacuna vasorum**), is designated as the external iliac vein. Passing medially and posteriorly of the artery, the external iliac vein joins with the internal iliac vein in the region of the sacroiliac joint to form the common iliac vein. The external iliac vein drains two veins, **inferior epigastric vein** (v. epigastrica inferior) and **deep circumflex iliac** vein (v. circumflexa ilium profunda) accompanied by arteries of the same name, which sometimes flow into it from a common trunk.

The veins of the lower extremity

Just as with the upper extremity, the veins of the lower extremity are divided into **deep** and **superficial, or subcutaneous**, veins, which pass independently of the arteries.

The **deep veins** of the foot and crus (leg) are binary and they accompany arteries of the same name. **V. poplitea**, which is comprised of all the deep veins of the crus and foot (), constitutes a single trunk lying in the popliteal fossa posteriorly and somewhat laterally of the artery of the same name. **V. femoralis** is single; it originates laterally of the femoral artery but, then, passes gradually to the posterior surface of the artery, and as it rises higher, it passes onto the medial surface. From this position the vein runs under the inguinal ligament into the lacuna vasorum. The veins flowing into v. femoralis are all binary.

The largest of the **subcutaneous** veins of the lower extremity are **two trunks**: **v. saphena magna** and **v. saphena parva**.

The **large saphenous vein** (vena saphena magna) originates on the dorsal surface of the foot from **rete venosum dorsale pedis** and the **arcus venosus dorsalis pedis**. Having received a few small branches from the side of the sole, it passes upward along the medial side of the malleolus, crus and femur. In the upper one-third of the femur, it bends onto the anteromedial surface and, lying on the broad fascia (fascia lata), runs toward the hiatus saphenus. At this point, it drains into the femoral vein, passing over the lower horn of the crescent-shaped edge. V. saphena magna quite often is binary with both its trunks draining separately into the **femoral vein**. Among the other subcutaneous veins flowing into the femoral vein, mention should be made of **v. epigastrica superficialis, v. circumflexa ilium superficialis,** and **vv. pudendae externae**, which accompany arteries of the same name. Some of them drain directly into the femoral vein; others drain into v. saphena magna as it flows into the region of the hiatus saphenus.

The **small saphenous vein** (v. saphena parva) originates on the lateral side of the dorsal surface of the foot, passes below and behind the lateral malleolus, and then rises along the posterior surface of the crus. At first it runs along the lateral edge of Achilles tendon and then proceeds upward along the middle of the posterior segment of the crus corresponding to the groove between the heads of m. gastrocnemius (Pirogow canal). When it reaches the lower angle of the popliteal fossa, v. saphena parva drains into the popliteal vein. V. saphena parva is joined by branches to v. saphena magna.

Distribution of the veins

1. In the veins the blood flows through the greater part of the body (the trunk and limbs) against the force of gravity and, therefcre, slower than in the arteries. The balance in the heart is achieved because most of the venous bed is much wider than the arterial bed. The greater width of the venous bed is the result of the following anatomical adaptations: the larger calibre of the veins, their greater number, the paired attendance of the arteries, the presence of veins not accompanying arteries, the greater number of anastomoses, the denser venous network, the formation of venous plexuses and sinuses, and the presence of a portal system in the liver. Because of this, venous blood flows to the heart along three large vessels (two venae cavae and the coronary sinus, in addition to the small veins running to the heart), while from the heart blood flows only along the aorta.

2. **Deep veins** accompanying the arteries (venae commitantes) are distributed according to the same laws as the arteries they accompany. Moreover, most of them accompany the arteries in pairs. Where the venous outflow is most hampered, i.e., in the extremities, the veins are mainly paired, since this arrangement is the result of evolution in four-legged animals whose torsos are horizontal, while both pairs of limbs are perpendicular to the ground.

3. Many **superficial veins** lying under the skin accompany the nerves of the skin, although a significant number form subcutaneous venous plexuses with no connection to either the nerves or the arteries.

4. **Venous plexuses** are mainly encountered in **internal organs** that change in volume in cavities with inflexible walls. The plexuses facilitate the flow of venous blood when the organs increase in size and are compressed by the walls. This explains the abundance of venous plexuses around the organs of the small pelvis (urinary bladder, uterus, rectum), in the vertebral canal, where the pressure of the cerebrospinal fluid constantly fluctuates, and in similar places.

5. In the **cranial cavity** where the slightest impediment to the venous outflow has an immediate effect on brain functions, there are, besides the veins, venous sinuses with inflexible walls formed by the dura mater. These spherical adaptations lie mainly where the processes of the dura mater are attached to the bones of the skull (at the seams of tegmental bones and bone sulci of analogous sinuses).

6. Among the special adaptations are the diploic veins, venae diploicae and vv. perforantes, which make communication between external jugular venous bed and internal jugular venous bed. This fact plays the most important role in equilibration of intracranial pressure with atmospheric pressure.

Specific features of blood circulation of the foetus

The fetus is supplied with oxygen and nutrients from the blood of the mother through the **placenta**. Placental circulation originates in the following way. Arterial blood enriched by oxygen and nutrients flows from the mother's placenta into the **umbilical vein** which enters the body of the fetus in the region of the navel and passes upward to the **left longitudinal sulcus** of the liver. At the level of the porta hepatis, v. umbilicalis divides into **two branches**, one of which drains immediately into the **portal vein**, while the other, the **ductus venosus Arantii**, passes along the inferior surface of the liver to its posterior edge where it empties into the trunk of the **vena cava inferior**.

The supply of pure arterial blood from one of the branches of the umbilical vein through the portal vein allows **the liver** to reach its relatively **large size**. The large size of the liver is connected with function of haemopoiesis performed by the liver. Essential in the developing organism, haemopoiesis predominates in the foetus and diminishes after birth. After passing through the liver the blood flows through the hepatic veins into the **vena cava inferior**.

Thus, all the blood from v. umbilicalis drains directy (through the ductus venosus) or indirectly (through the liver) into the vena cava inferior where it mixes with the venous blood flowing through the latter from the lower half of the foetus's body. The mixed (arterial and venous) blood flows along the vena cava inferior into the **right atrium**. From the right atrium it is directed by the **valve of the vena cava inferior** (valvula venae cavae inferioris), through the **foramen ovale** (situated in the septum separating the atria) into the **left atrium**. From the left atrium the mixed blood goes to the left ventricle and then into the aorta, bypassing the pulmonary circulatory system, which is not functioning yet.

Besides blood from the vena cava inferior, blood from the **vena cava superior** and the **venous (coronary) sinus** of the heart also flows into the right atrium. Venous blood draining into the vena cava superior from the upper half of the body flows further into the **right ventricle** and, from there, into the **pulmonary trunk**. Since the lungs are not yet functioning as a respiratory organ, however, only an insignificant part of the blood reaches the parenchyma of the lungs and, from there, flows along the pulmonary veins to the left atrium. The greater part of the blood from the pulmonary trunk flows along the **ductus arteriosus (Botalli)** into the descending aorta and, from there, to the internal organs and lower extremities. Thus, despite the fact that mixed blood circulates through all the vessels of the fetus (with the exception of v. umbilicalis and the ductus venosus until it drains into the vena cava inferior), its quality below the point where the ductus arteriosus joins the vena cava inferior deteriorates greatly. Consequently, the upper part of the body (the head, neck and upper limbs) receives blood that is richer in oxygen and nutrients than the lower part of the body, which is not as well supplied as the top and, thus, is slower to develop. This explains the relatively small dimensions of the pelvis and the lower extremities in the newborn. This specific shape of newborn permit the foremost part of body (head) to dilate the birth way of mother and finally after exiting the head the remnant part (abdomen and lower limb) will be born without effort.

The act of birth produces radical qualitative changes in the vital processes of the organism. The developing fetus transfers from the medium of the intrauterine life with its relatively constant conditions (temperature, humidity, and so on, inclusive social) into the medium of the external environment (world) with its continually changing conditions. As a result metabolism changes radically, as do the means of nourishment and respiration. Instead of receiving ready nutrients through the blood, the newborn receives food through the digestive tract where it is subject to digestion and absorption. Oxygen, instead of reaching the organism through the blood of the mother, comes from the atmosphere as the organs of respiration begin functioning. These developments also affect blood circulation.

During birth a sharp transition takes place from placental to pulmonary circulation. With the first inhalation and expansion of the lungs with air, the pulmonary vessels dilate greatly and fill with blood. The ductus arteriosus then collapses and is obliterated within the first **eight to ten days**, transforming into the **ligamentum arteriosum**.

The umbilical arteries involute during the first two to three days of life, the umbilical vein somewhat later (on the sixth to seventh day). The flow of blood from the right into the left atrium through the oval orifice stops immediately after birth, because the left atrium fills with blood from the lungs and the blood pressure between the left and right atria levels out. The closure of oval orifice, however, occurs much later than the obliteration of the ductus arteriosus, and, in many cases, it is preserved throughout the first year of life. In one-third of all cases, it is preserved for life.

X-ray examination of the blood vessels

It is now possible to examine practically all the blood vessels on a living human being roentgenologically using angiography or vasography. The entire length of the aorta or any of its separate parts: ascending, arch, thoracic and abdominal, with the large arteries of the abdominal cavities arising from it (splenic, renal, and others) may be examined using various types of aortography. Using computers (CT) it is possible to in reach the quality of images and also perform 3D modeling of examine vessels.

The aorta and other vessels

X-ray examination of the aorta is conducted simultaneously with that of the heart. Rising upward, with its ascending segment bulging to the right, the aorta in an anterior position forms the upper arch of the left contour of the cardiovascular shadow. In cadavers the aorta is collapsed and does not protrude beyond the limits of the vena cava superior, the vein which actually forms the upper arch of the right contour of the median shadow. In living persons the aorta, dilated by blood, straightens out and protrudes beyond the margin of the vena cava superior. The arch of the aorta then turns to the left and to the back toward the spinal column. Bending downward, the descending segment creates the upper arch of the left contour of the cardiovascular shadow.

In the left (mamillary) oblique position, all the parts of the aorta are visible: the ascending segment, the arch and the descending segment, up to the diaphragm. The light oval space, blocked in front by the shadow of the heart and above and behind by the aorta (retrocardiac pulmonary field), is called the "**aortic window**". This window may be narrow or wide, depending on the shape of the chest, the level of the diaphragm, and the position of the heart. The aorta is fixed at two points (at the point where it emerges from the heart and at the hiatus aorticus) and easily displaced, changing its height and the distance between its ascending and descending parts, i.e., the width of the "aortic window". In people with a wide but short chest and a diaphragm located high in the chest, the aorta will appear high and "**extended**" when the heart is viewed in a horizontal position. In this case the ascending and descending segments of the aorta are more removed from each other: the aortic window is widened and the aortic arch straightens out relatively. In people with a long, narrow chest and low diaphragm, the aorta appears low and contracted, when the heart is in a vertical position.

The abdominal aorta can be seen with aortography by injecting a radiocontrast medium into its lumbar segment. Its bifurcation ls also visible as well as the passage of both iliac arteries and their large branches. The difference in the topography of the abdominal aorta in a living person and a cadaver is quite obvious here. In the cadaver the aorta appears as an even straight trunk somewhat to the left of the median ine. The intravital tones and mobility of neighbouring organs in living persons may cause the aorta to move slightly to the right and to arch convexly somewhat to the right as well.

The other blood vessels can be examined in living human beings with X-rays and radiocontrast substances which heighten the contrast between the vessels. Radiocontrast substances are injected directly into the vessels at the moment the X-ray is taken. This method is called vasography.

Injection of a radiocontrast medium into the brachial or femoral arteries produces the image of the large arterial trunks of the extremities (**arteriography**). Selective arteriography, involving injection of the radiocontrast medium only into the lumen of the chosen artery, allows the X-ray examination of the other arteries. This ensures a clear picture of the entrance of the artery into the hilum of the given organ (the spleen, liver, or kidneys).

In a living person the **splenic artery** may appear not as a straight trunk Passing along the upper margin of the pancreas to the spleen (as it appears in the cadaver), but as a sharply winding coiled. The tortuousness of the spiral depends on the mobility of the spleen: if the spleen moves toward the median line, the splenic artery winds more sharply and vice versa. The same true of other arteries supplying mobile inner organs. In a cadaver they appear as straight and even trunks subject to the law of the shortest distance. In live subjects the arteries are twisted and spiral.

X-ray examination of the arteries of the parenchymatous organs reveals not only the **extraorganic** vessels but the **intraorganic** vessels as well. In the kidney, in particular, two phases of the advance of the radiocontrast medium have been noted: (1) vasographic, when the substance moves along the vessels; and (2) nephrographic, when it penetrates the urinary canaliculi.

The common carotid artery is studied in arterioencephalography angiography of the brain. The X-rays reveal the division of the artery into the internal and external carotid arteries and their ramification in the region of the head and brain.

Angiography of the extremities clearly reveals the main arteries ith all of their branches and ramifications. Since the bones appear automatically on the radiographs of any part f the body, the skeletopy of the arteries is easily determined.

The venous system can also be examined in living human beings with the injection of radiocontrast substances and subsequent roentgenography **(venography)**. This method produces the X-ray picture of most of the large (venae cavae, cardiac, and main veins) and small veins.

The veins of the extremities and intraorganic veins may also be successfully X-rayed. By introducing a radiocontrast medium into the umbilical vein, scientists produced a picture of the portal vein of the liver and its branches inside the liver (**portography**). At the same time the radiograph revealed extremely fine veins of a calibre usually visible only on corrosive preparations of liver specimens.

One of the methods of roentgenological examination of live subjects, electroroentgenography, can reveal the finest ramifications of the blood vessels in parenchymatous organs such as the lungs. As a result, the X-ray picture of the intraorganic vessels in a living human is in no way inferior to one obtained by injection, corrosion, or diminished intensity. Examination of the vessels of a living human yields more exact anatomical information since it complements this information with physiological data.

The lymphatic system

The **lymphatic system** (systema lymphaticum) constitutes part of the vascular system (second vascular system) and may be considered a supplementary bed of the venous system. It develops in close relationship with the venous system and shares with it similar structural features (the existence of valves, the direction of the flow of lymph from the tissues to the heart). The main functions of the lymphatic system consist in conducting lymph from the tissues into the venous bed, in rendering harmless the foreign particles, bacteria and so on, that find their way into the organism, and in forming lymphoid elements (lymphopoiesis), which participate in immunological reactions. In addition, the cells of malignant tumours spread along the lymphatic system; a thorough knowledge of the anatomy of the lymphatic system is essential in determining these paths.

The lymphatic system is classified according to function into tho following groups:

1. pathways that conduct lymph: vascular and nonvascular
2. lymph nodes, **nodi lymphatici**

The **lymphatic system** is a system of **tubes closed** at one end and opening at the other end (central) into the venous bed.

The lymphatic vessels consist of the following parts:

1. the lymph capillaries;
2. the lymphatic postcapillaries;
3. the lymphatic vessels;
4. the lymphatic trunks
5. the lymphatic ducts

Morpho-functional Unit of the lymphatic system is formed by:

Regional lymphatic Complex

- Lymphatic vessels
- Lymphatic nodes
- Nonvascular pathways of circulation

The lymph capillaries

The **lymph capillaries** are first segment of the lymphatic vessels, starts blind, absorb and resorb colloid solutions of protein substances that are not absorbed by the blood capillaries from the tissues (lipids and liposoluble vitamins, proteins). The lymph capillaries also help the veins to drain the tissues by absorbing aqueous fluid and the colloids and crystalloids dissolved in it. They also remove cells or cellular fragments (foreign particles, bacteria, and tumor cells). In such way is formated **lymph** (fluid without color or light pal color, pH 7,5-7,9, composed by water, salts, fats, proteins, hormones, ferments, colloids, crystalloids, there are lymphocytes and polymorpho-nuclear cells, but are absents erythrocytes and thrombocytes, lymph will path in its way at least through one lymph node, daily is produced around of 2-4 liters of lymph).

The lymph capillaries perform these functions through a system of endothelial tubes the wall is built by one layer of endothelium, which made clefts and valves looks inside. Its activity is maintained by anchored filaments that are fixated in connective tissue. It has no basal membrane and there are no pericytes around it. The lymph capillaries are larger than blood capillaries (20-200 mkm).

Its penetrate all organs of the body except on cartilages, dentin and dental enamel, nail and hear, cornea and sclera of eye ball, lens of the eye, epithelial tissue of epithelial coat of the skin and mucous membranes (there are no any vessels ether blood or lymph one), the brain with meninges, splenic paren chyma, red bone marrow, renal glomeruli, internal ear and placenta with umbilical cord.

The structure of the initial lymphatic networks varies. It is determined by the structure and function of the organ and the properties of the connective ssue in which the lymph capillaries have been laid. The direction of the loops of these capillaries corresponds to the direction and position of the fasciculi of connective tissue, muscle fibres, glands, and other structural cements of the given organ, built superficial and deep plexus.

In the **lymphatic postcapillaries** is possible to observe the first valves that control the one way flow of limph. The structure of them in rest is similar to capillaries.

Lymphatic vessels

The transition of lymph capillaries into lymphatic vessels is determined by changes in the structure of the wall (pluristratified) and the appearance of **a valve** (semi lunar type), in the vessel, which permit flow of lymph only to the single direction. The **intraorganic lymphatic vessels** form widely looped plexuses and run parallel to the blood vessels in the connective-tissue layers of the organ. Also there are extra organic vessels that built intravisceral and extravisceral; superficial, deep plexuses. Depend on functional status there are following lymphatic vessels:

- With transversal strips
- Reticular type
- Gofer type
- Pellucid type

The morpho-functional unit of the lymphatic vessel (**micro-segment**) is considered the part of vessel between 2 paires of valves (inclusive the caudal). This region is called **LYMPHANGION**. It works like a small pump, myocytes of the wall - middle layer activate automatically as a heart (rhythmically, biphasic with systole and diastole) pushing lymph to distal end. In the structure of lymphangion we destinguish: the muscular sheath and the valve sinus

Classification of lymphangions by shape is: cylindrical, spherical, oval, long, triangular, flat; short etc.

At the junction of vessels is formed **lymphatic cistern**. Vessels that bring lymph toward the cistern are afferent **vessels** (2-5), that vessels which carry lymph from the cistern are **efferent** (1-2).

Macromicrosegment of the lymphatic vessel is segment between 2 pair of cisterns, including caudal one. Also we distinguish **macro-segment** of the lymphatic vessel, which represents the segment between 2 pair of nodes.

Abducent lymphatic vessels (extraorganic) leading to various lymph nodes arise from every organ or part of the body. After passing through the last group of lymph nodes, the lymph collectors form **lymph trunks**, corresponding in number and position to the large parts of the body.

Thus, the main lymph trunk for the lower limb and pelvis is the **truncus lumbalis**, which forms from the efferent vessels of the lymph nodes located around the aorta and vena cava inferior. For the upper extremity the main lymph tunk is the **truncus subclavius** which passes along v. subclavia. The head and neck are supplied by the **truncus jugularis** passing along v. jugularis interna. In addition, the thoracic cavity is served by the paired **truncus bronchomediastinalis**. The unpaired **truncus intestinalis** is sometimes encountered in the abdominal cavity.

All these trunks eventually join in **two terminal ducts**: **the ductus lymphaticus dexter** and **ductus thoracicus**, which drain into the large veins, mainly the internal jugular vein (venous angle).

The **right lymphatic duct** (ductus lymphaticus dexter) **-** is formed at the junction of right subclavicular (truncus subclavius dexter), jugular (truncus jugularis dexter) and bronchomediastinal (truncus bronchomediastinalis dexter) trunks. It is no more than 10-12 mm long and receives lymph from the right side of the head and neck, from the right upper extremity, and the right mediastinal trunk, which collects lymph from the right half of the thoracic internal organs and the right half of the thoracic wall. The right lymphatic duct drains into the right subclavian vein. It is quite often absent, in which case the three trunks mentioned above drain independently into the subclavian vein.

Thoracic lymphatic duct – represents the largest lymphatic vessel (from 30 to 41 cm long), that drainages in the left venous angle. It is formed as union of right and left lumbar trunks (truncus lumbalis dexter and sinister) with intestinal (truncus intestinal) one at the level of Th 12 - L2. At this level of junction (regio abdominalis) could be **cisterna chyli** (75 per cent). Arising in the abdominal cavity, the thoracic duct passes into the thoracic cavity through the **aortal orifice**. There it grows together with the right peduncle of the diaphragm, the contractions of which help the lymph to move along the duct ("**passive lymphatic heart**"). On entering the thoracic cavity, the duct rises in front of the spinal column to the right of the thoracic aorta, behind the oesophagus and, then, behind the aortic arch. Reaching the aortic arch at the level of the third-fifth thoracic vertebra, the duct begins inclining to the left. In thoracic region is located between azigos vein and thoracic aorta, receive tributaries by right and left bronhomediastinal trunk and intercostals lymphatic vessels.

At the level of the seventh cervical vertebra, the thoracic duct forms an arch with its convexity facing upward and drains into the left internal jugular vein or into the angle of its confluence with the left subclavian vein (**angulus venosus sinister**). At this place thoracic duct arches and branches as “delta” - 2-4 (twigs). The thoracic duct is supplied inside with two well-developed folds which prevent blood from flowing into it when it drains. Three trunks drain into the upper part of the thoracic duct: the **left mediastinal trunk** (truncus bronchomediastinalis sinister), which collects lymph from the left half of the walls and organs of the thoracic cavity, the **left subclavian trunk** (truncus subclavius sinister), which collects lymph from the left upper extremity, and the **left jugular trunk** (truncus jugularis sinister), which collects lymph from the left half of the neck and head. Thus, the thoracic duct collects three-fourths of all lymph in the body with the exception of lymph from the right half of the head and neck, the right arm, and the right half of the chest and thoracic cavity. The lymph from these areas flows into the right lymphatic duct.

The thoracic duct and the large lymphatic vessels have vasa vasorum. All lymphatic vessels have both afferent and efferent nerves in their walls

Lymph nodes

Before entering the thoracic duct or the right lymphatic duct, the lymph passes through several lymph nodes, **nodi lymphatici**, which are situated singly or, more frequently, in groups on the paths of the lymphatic vessels. The nodes are round or oval formations, ranging in size from a grain of wheat to a bean. The lymph node is covered by a connective-tissue **capsule** from which the **septa trabeculae** protrude into the node. Lymphoid tissue, in the form of **cortical, paracortical** (paracortical zone), and medulla, lies between the trabeculae. There are spaces lymphatic sinuses between the trabeculae and the lymphoid tissue. The lymph comes to the lymph node through **afferent lymphatic** vessels (vasa afferentia), which enter its convex side and open into sinuses (subcapsular, cortical, medullar and hilar). In the sinuses the lymph flow slows down and sweeps along with it the lymphocytes forming in the tissue of the node (germinal center in cortex); the lymph then departs through **efferent lymph vessels** (vasa efferentia) which exit through the porta (hilum) on the concave side of the node.

Thus, lymph nodes are distinguished from lymphoid organs and tonsils, which have only **efferent lymphatic vessels** and lack afferent lymphatic vessels. The lymphatic vessels of any organ pass through certain regional groups of nodes located near the given organ. The regional nodes for the internal organs are usually located at their hilum. In the "soma" large accumulations of lymph nodes are situated in protected and mobile places near the joints, the movements of which help the lymph to pass through the nodes. Thus, large groups of nodes are concentrated on the lower extremity in the popliteal fossa and the groin; on the upper extremity by the elbow joint and the axillary fossa; on the trunk in the lumbar region and the neck.

The lymph nodes have arteries and veins which are branches (arteries) and affluents (veins) of neighbouring vessels. The nodes are also characterized by afferent and efferent innervation. Since lymph nodes can arrest foreign bodies (bacteria, tumorous cells, etc.) that enter them through the lymphatic vessels, substances of pathogenic origin may accumulate in the nodes. Knowledge of their topography can be of great diagnostic and therapeutic significance.

The lymphatic system in various parts of the body

The lymphatic vessels of the head and limbs (i.e., of the soma) are divided into **superficial** and **deep vessels**, separated by the deep fascia of the given region. Thus, the lymphatic vessels of the skin, subcutaneous tissue, and part of the fascia, are superficial, while all other vessels, i.e., the lymphatic vessels lying under the fascia, are deep. The deep lymphatic system of the soma is built as follows. The deep lymphatic vessels arising from the capillary lymph networks of joint capsules, muscles, tendons, fasciae, nerves, and so on run, at first, as components of the neurovascular bundles of these organs and then drain into the lymph collectors of the given part of the body. In their turn the lymph collectors accompany large arterial and venous trunks and drain into the regional lymph nodes. In the **cavities** vessels and nodes are devided in **parietal** and **visceral**.

Lymphatics the lower extremity

The lymph nodes of the lower extremity are located in the following places.

1. Popliteal fossa —popliteal lymph nodes (nodi lymphatici poplitei).

2. Inguinal region —inguinal lymph nodes (nodi lymphatici inguinales). They lie immediately under the inguinal ligament and are divided into **superficial and deep inguinal** lymph glands.

a) superficial inguinal nodes (nodi lymphatici inguinales superficiales) are located on the wide fascia of the femur below its perforation by v. saphena magna;

b) deep inguinal nodes (nodi lymphatici inguinales profundi) are locatea in the same region as the superficial glands although under the wide fascia.

The superficial lymphatic vessels drain into two groups of collectos running the length of v. saphena magna to the medial group of the superficial inguinal nodes and along v. saphena parva to the popliteal nodes of the posterolateral group.

The posterolateral group of collectors and the popliteal nodes receive lymph from the skin, subcutaneous tissue, and superficial fasciae of a small region of the leg (the fourth and fifth toes, the lateral edge of the foot, the inferior lateral surface of the crus, and the lateral part of the gastrocnemius region). From all other parts of the leg, the lymph flows into the medial group of collectors and then into the inguinal nodes without interruption in the popliteal nodes. The superficial lymphatic vessels of the upper one-third of the thigh drain into the inguinal nodes, which also receive the superficial vessels of the gluteal region, the anterior abdominal wall, and the external sexual organs.

The deep lymphatic vessels of the foot and crus, including the articular sac of the knee joint, drain into the popliteal nodes. From there the lymph flows through the deep collectors attendant to the femoral artery until it reaches the deep inguinal nodes. These same collectors also receive lymph from the deep tissues of the thigh. As a result, the large group of nodes located in the inguinal region collects lymph from the entire lower limb, the anterior wall of the abdomen (below the navel), the gluteal region, the perineum and external sexual organs, and partly from the internal genital organs.

The efferent vessels of the inguinal nodes run the length of the external iliac artery and vein to the iliac lymph nodes from where the lymph passes into the truncus lumbalis.

Lymphatics the pelvis

In the pelvis the lymph nodes are mainly located along the blood vessels, as well as on the surface of the internal organs.

- Ganglioni **<u>viscerales</u>**:
  - Ganglioni lymphatici paravezicales
  - Ganglioni lymphatici parauterines
  - Ganglioni lymphatici paravaginales
  - Ganglioni lymphatici pararectales
- Ganglioni **<u>parietales</u>**:
  - Ganglioni lymphatici subaortales
  - Ganglioni lymphatici iliaci communes
  - Ganglioni lymphatici iliaci interni
  - Ganglioni lymphatici iliaci externae
  - Ganglioni lymphatici gluiteales
  - Ganglioni lymphatici obturatorii
  - Ganglioni lymphatici sacrales

Lymphatics the abdomen

The lymphatic vessels of the region above the navel pass upward and laterally of nodi lymphatici axillares, while the vessels of the area below the navel descend to nodi lymphatici inguinales.

In the abdominal cavity are distinguished: 1) **parietal** or abdominoaortal nodes situated around the aorta and vena cava inferior and 2) **visceral** nodes which are distributed along the trunks and branches of the celiac artery and the superior and inferior mesenteric arteries. The total number of abdomino-aortal nodes reaches 30 to 50. In relation to the aorta they are classified as left lateroaortal, preaortal, or retroaortal nodes; in relation to the vena cava inferior they are divided into laterocaval, precaval, retrocaval, and interaortocaval nodes. All of these nodes may be generally classified as aortic lymph glands (nodi lymphatici lumbales).

The **visceral nodes** of the abdominal cavity may be subdivided into two large groups: 1) nodes of the branches of the **coeliac artery** and 2) nodes of the branches of the **mesenteric arteries**, mesenteric lymph glands (nodi lymphatici mesenterici).

Nodes of the **first group** are given names relative to the proximate arteries and organs, e.g. nodi lymphatici coeliaci, gastrici sinistri and dextri, hepatici, pancreaticolienales, pylorici.

The **second group**, located along the mesenteric arteries, are extremely numerous (about 300). They are laid out in the thickness of the mesentery of the small and large intestine and have been described together with their lymphatic vessels. The lymphatic vessels and nodes of the organs of the abdominal cavity are described in detail in the descriptions of the anatomy of each organ (see the section on splanchnology).

The **small intestine** has a particular system of “milky” lymphatic vessels. A meshwork of lymph capillaries runs through all the strata comprising the wall of the small intestine, i.e., the mucous, submucous, muscular, and serous layers. They lie in the mucous and submucous membranes of the intestine and continue further into the mesentery, transporting absorbent fat which turns the lymph into a milky emulsion (chyle). Other nutrients are absorbed by the venous system and carried to the liver by the portal vein. The efferent lymphatic vessels of the duodenum pass to the pancreato-duodenal lymph nodes. The efferent lymphatic vessels of the jejunum and ileum pass through the thickness of the mesentery to the mesenteric nodes. There are three groups of lymphatic vessels can be distinguished in the mesentery of the small intestine: 1) peripheral group; 2) the median group, and 3) the central group.

As they pass through the mesentery, the chylous vessels are interrupted by mesenteric lymph nodes arranged in four lines. The nodes of the first line are located along the mesenteric edge of the intestine; the nodes of the second line are slightly removed from the edge. The nodes of the third line are gathered around the root of the mesentery, and the nodes of the fourth line are concentrated in the root of the mesentery. Lymph from the mesenteric nodes flows mainly to the lateroaortal and preaortal nodes and, from there, into the truncus lumbalis sinister and further into the thoracic, duct. Sometimes part of the efferent vessels of the mesenteric and other visceral nodes of the abdominal cavity gather into short trunks called **trunci intestinales**, which drain either directly into the beginning of the thoracic duct or into the left (rarely into the right) lumbar duct.

Lymph from the large intestine flows into nodi lymphatici ileocolici, colici dextri, colici medii, mesenterici inferiores, and colici sinistri located along the vessels of the same names.

Lymphatics the thoracic cage

Parietal and visceral lymph nodes can be distinguished in the thoracic cage.

Parietal nodes are comprised of the following groups:

1. Posterior —intercostal (nodi lymphatici intercostales).
2. Anterior (nodi lymphatici parasternales) - along the length of the a. thoracica interna.

Visceral nodes are subdivided into five groups:

1. Anterior and posterior mediastinal nodes (nodi lymphatici mediastinales anteriores and posteriores).
2. Tracheal nodes (nodi lymphatici tracheales), located laterally and posteriorly of the trachea.
3. Tracheo-bronchial nodes (nodi lymphatici tracheobronchiales superiores and interiores), located in the region of the bifurcation of the trachea.
4. Broncho-pulmonary nodes (nodi lymphatici bronchopulmonales), located in the hilum of the lung.
5. Pulmonary nodes (nodi lymphatici pulmonales), located in the lung along the branches of the pulmonary artery and bronchi.

The lymphatic vessels of the superficial coats of the anterior and lateral walls of the thoracic cage are directed mainly toward the nodi lymphatici axillares, while part of the trunks pass through the clavicle and drain into the deep cervical nodes.

From the inner side of the thoracic cage and from the pleura, the lymph vessels pass through the **nodi**

lymphatici intercostales into the thoracic duct and, more anteriorly, into the nodi lymphatici parasternales.

The efferent lymphatic vessels of the **mammary gland** pass from its lateral parts to the axillary nodes, from the posterior part to the supraclavicular and subclavicular nodes, and from the upper medial part to the peristernal nodes. The superficial vessels of both mammary glands and the vessels of the lower medial part of the gland are connected with the vessels of the pleura, diaphragm, and liver. During pregnancy and lactation the lymph bed of the gland expands; with the involution of the gland in old age, the bed contracts.

The lymphatic vessels of the diaphragm drain into nodi lymphatici phrenici located at the crura of the diaphragm, partly into the mediastinal nodes and partly into the nodi lymphatici parasternales.

Lymph from the organs of the thoracic cavity accumulates in two large trunks, the **truncus bronchomediastinalis dexter** and **sinister**. The former drains into the ductus lymphaticus dexter, the latter into the thoracic duct.

The efferent lymphatic vessels of different organs of the thoracic, abdominal, and pelvic cavities may either join en route to regional nodes or drain into common regional nodes, thus establishing communication between the flow of lymph from different organs. These connections are important in comprehending the paths along which cancer spreads.

Lymphatics the upper extremity

Lymph from the tissues and organs of the shoulder girdle, the adjoining part of the thoracic wall, and the entire free upper extremity accumulates in the subclavian trunk (truncus subclavius), which runs in the neuro-vascular bundle along v. subclavia. Its right branch drains into the ductus lymphaticus dexter or the right venous angle; its left branch drains into the thoracic duct or directly into the left venous angle. The regional lymph nodes of the upper extremity lie near the large joints in two large accumulations: one near the elbow joint, supratrochlear lymph glands (nodi lymphatici cubitales), and one near the humeral articulation, axillary lymph glands (nodi lymphatici axillares).

The axillary nodes, are situated in large numbers in the tissue of the axillary fossa and can be classified as folows.

Ganglionii lymphatici axillares (6 groups):

1. Gll. lymphatici laterales
2. Gll. lymphatici mediales (toracici)
3. Gll. lymphatici subscapulares (posteriores)
4. Gll. lymphatici inferiores
5. Gll. lymphatici centrales
6. Gll. lymphatici apicales

The superficial lymphatic vessels of the upper extremity consist of two groups: 1) the medial vessels pass from the middle and little fingers and the inside of the palm and the forearm along the medial side of the shoulder into the axillary nodes; part of the medial vessels accompany v. basilica and drain into nodi lymphatici cubitales; 2) the lateral superficial vessels run parallel to v. cephalica and flow into nodi lymphatici axillares superficiales. The superficial lymphatic vessels of the shoulder girdle and shoulder also drain into the axillary nodes.

The deep lymphatic vessels of the upper extremity carry lymph from the bones, joints, and muscles of the hand and forearm and, accompanying the radial and ulnar arteries, flow into the deep ulnar lymph nodes. From there the lymph flows along the collectors that accompany the brachial artery and reaches the deep axillary nodes. On the way they are joined by the deep lymphatic vessels of the shoulder. Lymph from an extensive area of the body—the upper extremity, the shoulder girdle, and the chest merges in the group of subaxillary nodes.

Lymphatics the head and neck

Lymph from the head and neck collects in the right and left jugular lymph trunks, the truncus jugularis dexter and sinister, which run on each side of the neck parallel to the internal jugular vein. The right trunk drains into the ductus lymphaticus dexter or directly into the right venous angle, the left into ductus thoracicus or directly into the left venous angle. Before flowing into the duct the lymph passes through the regional lymph nodes.

On the head lymph nodes group mainly along the border between the head and the neck. Among these groups of nodes we can note the following:

1 **Occipital lymph nodes** (nodi lymphatici occipitales) drain the lymphatic vessels coming from the posteroexternal part of the temporal, parietal, and occipital regions of the head.

2. **Mastoid lymph nodes** (nodi lymphatici retro-auriculares) collect lymph from the same areas as the occipital nodes as well as from the posterior surface of the floor of the auricle, the external acoustic meatus, and the tympanic membrane.

3. **Parotid lymph nodes** (nodi lymphatici parotidei), superficiales and profundi, collect lymph flowing from the forehead, temple, lateral part of the eyelids, external surface of the floor of the auricle, temporomandibular articulation, parotid and lacrimal glands, walls of the external acoustic meatus, tympanic membrane, and both auditory tubes.

4. **Submandibular lymph nodes** (nodi lymphatici submandibulares) collect lymph from the lateral side of the chin, the upper and lower lips, cheeks, nose, gums and teeth, medial part of the eyelids, hard and soft palates, 1-Jody of the tongue, and submandibular and sublingual salivary glands.

5. **Mandibular lymph nodes** (nodi lymphatici mandibulares) collect lymph from the eyeball, muscles of facial expression, mucous surface of the cheek, ips, and gums, muciparous glands of the oral cavity, periosteum of the region of the mouth and nose, and submandibular and sublingual glands.

6. **Submental lymph nodes** (nodi lymphatici submentales) collect lymph from the same regions of the head as the mandibular nodes, as well as from the tip of the tongue.

7. **Buccal lymph glands** (nodi lymphatici buccales) collect lymph from the mucous membrane of the cheek and the cheek muscle.

8. **Retropharyngeal lymph nodes** (nodi lymphatici retropharyngei) drain lymph from the mucous membrane of the nasal cavity and its accessory air-passage cavities, from the hard and soft palates, the root of the tongue, nasal and oral parts of the throat, as well as from the middle ear.

Lymph from the above nodes flows to the cervical nodes.

On the neck there are two groups of lymph nodes: **superficial** (nodi lymphatici cervicales superficiales) and **deep** (nodi lymphatici cervicales profundi).

Ganglioni lymphatici cervicales superficiales

- Gll. lymphatici jugulares externi
- Gll. lymphatici jugulares anteriores

Ganglioni lymphatici cervicales profundi

Anteriores

- Gll. lymphatici prelaringei
- Gll. lymphatici pretraheales
- Gll. lymphatici paratraheales

Laterales

- Gll. lymphatici Cervicales laterales profundi (jugulares interni) – **superiores** et **inferiores**
- Gl. jugulodigastricus

The **superficial lymph nodes** are divided into **anterior nodes**, located below the hyoid bone between the two main neurovascular nodes of the neck, and the **lateral nodes**, situated along v. jugularis externa.

The **deep lymph nodes** form a chain along the length of v. jugularis interne as well as along the nerves of the spinal cord and a. transverse colli. They play a major role in the outflow of lymph from the organs and tissues of the head and neck. It is possible to distinguish nodes in front of the larynx, the thyroid gland, and the trachea, nodes running parallel to the sides of the trachea along the recurrent nerves, and supraclavicular nodes. All deep cervical lymph nodes can be divided generally into two large groups: superior and inferior.

Among the superior deep cervical lymph nodes, the **nodus lymphaticus jugulodigastricus** deserves special attention. Located on the internal jugular vein at the level of the greater horn of the hyoid bone, this node receives lymph from the vessels of the posterior third of the tongue and becomes greatly enlarged when this part of the tongue is affected by cancer. The nodus lymphaticus jugulo-omohyoideus is one of the most important of the inferior deep cervical lymph nodes. This node lies on the internal jugular vein directly over m. omohyoideus. It receives the lymphatic vessels f the tongue either directly or through the mental or submaxillary lymph nodes, which may contain cancerous cells.

The lymphatic vessels of the skin and muscles of the neck pass to nodi lymphatici cervicales superficiales. Those of the larynx (the lymph plexus of the mucosa above the vocal chords) flow through the membrane thyreohyoidea to nodi lymphatici cervicales profundi (superiores). The lymphatic vessels of the mucosa below the rima glottidis pass along two routes forward through the membrane thyreohyoidea to nodi lymphatici cervicales profundi (prelarynreal) and backward to the nodes located along n. laryngeus recurrens (tracheal). The lymphatic vessels of the thyroid gland flow mainly to nodi lymphatici cervicales profundi (prethyroid) and from the isthmus to the anterior superricial cervical nodes. From the pharynx and palatine tonsils, lymph flows to nodi lymphatici retropharyngei and cervicales profundi.

Factors, which help lymph circulation:

- Somatic and Visceral muscular activity (e.g. intestinal peristaltic movement)
- Aspirate action of a pleural cavity during respiration
- High pressure of lymph capillaries
- Rhythmic and phase muscular contractions (systolic and diastolic) of lymph vessels
- Motor activity of the lymphatic nodes
- Pulsation of blood vessels.

The collateral flow of the lymph

In case of occlusion or cutting of the lymphatic vessels, the surgical removal of the lymph nodes, their occlusion by cancer cells, or affection by chronic inflammatory processes, the natural patency of the lymph bed is disturbed and the lymph can no longer flow in the usual direction. The lymphatic system, however, has developed certain functional adaptations to restore the disturbed flow. If necessary, neighbouring auxiliary lymphatic vessels, which had not served previously as the main channels for the outflow of lymph from a given organ or part of the body, may become the principal or even channels for draining lymphatici The lymph thus begins to flow along :direct lateral routes in what is called indirect or collateral lymph circulation, or to be more precise, collateral lymph flow. Changes in the direction of the lymph flow caused by obstruction are important in the development of collateral lymph flow.

Under normal conditions the lymph flow is directed by the valves of the lymphatic vessels to the right and left venous angles, where it drains into the vascular bed. Thus, collateral lymph flow to bypass obstacles along the main route is possible only when the direction in which the lymph flows is changed, i.e., only when the flow of lymph is reversed (retrograde). Distal to the obstruction, the lymph stagnates and the lymphatic vessels dilate; the valves weaken and the lymph reverses the direction of flow.

Three stages can be distinguished in the development of indirect lymph flow when the main collectors are intercepted or the nodes removed:

1. the early period (one to three weeks after the main flow of lymph has been disturbed). During this period the main path is not used, and lymph flows along collaterals that had existed formerly under normal conditions. In addition, new indirect routes are opened by the dilatation of the narrow canals of lymph networks under the pressure of lymphatici. Thus, during this period lymph flows out only along indirect routes into neighbouring lymph nodes;

2. the middle period (three to six weeks after impairment of the main lymph flow). Direct anastomoses between the ends of the interrupted flow begin developing in this period, as a result of which both the main and the collateral paths function simultaneously;

3. the end period (from six weeks to six months and later) —the full restoration of the disrupted principal route along the newly formed anastomosis, as a consequence of which all the indirect routes stop filling.

Thus, the system of collateral lymph flow involves normally existing auxiliary routes (collaterals) and newly developed lymphatic vessels which connect the segments of the disrupted route (anastomoses). The collateral lymph flow is important in understanding and predicting the spread of malignant tumours and infectious processes.

Anatomy of the lymphatic system of a living person

Roentgenolymphography, first developed in the Soviet Union, makes it possible to see the lymphatic vessels and nodes on a live subject.

The method is currently used to study the lymphatic vessels of the limbs, pelvis, thoracic gland, tongue, and the abdominal cavity. The method reveals the thoracic duct in its entire length. There are currently two types of roentgenolymphography:

1. **indirect**, when the X-ray contrast medium is infused into the skin, under the skin, or into the thickness of the tissue. A "depot" of the medium is thus created; it is absorbed along the lymphatic vessels and produces

shadows of the vessels and nodes on the radiograph;

2. **direct**, when the X-ray contrast medium is injected directly into the lymphatic vessel; the picture of the lymphatic channel in any part of the body is produced by this method. The radiograph shows the networks of lymphatic vessels, the larger collectors that form from these vessels with clearly outlined thickenings at the valves, the merger of lymph collectors into lymphatic trunks and ducts, and, finally, the drainage of the ducts into venous angles. The shadows of lymph nodes can also be seen very well, and one can judge the shape, size, position, and number of nodes by these shadows.

The lymph nodes are filled with the X-ray contrast medium in three stages: 1) filling; 2) maximum contrasting; 3) evacuation.

The entry and exit of the vessels into and from the nodes is clearly visible with the afferent lymphatic vessels flowing in the convex side of the node and the efferent vessels flowing out of the porta of the node on the concave side.

The X-ray pictures of the lymphatic vessels in cadavers and living persons differ.

1. In roentgenolymphography of cadavers all the lymphatic vessels and nodes of a given area of the body are revealed, and a postmortem X-ray picture reflects the anatomy of the lymph bed completely. This can be explained by the absence of a live tonus in the vessels and of physiological obstacles in the path of the lymph flow.

2. Roentgenolymphography of living persons, however, reveals only regional lymph vessels and nodes of any given part of the body, which lie along the shortest route and which are free from physiological obstacles at the moment of injection.

Because of changes in a live tonus and physiology, the lymphatic vessels and nodes of a given region become visible only gradually and in a certain order and at a certain time. Thus, injection of one part of the lymph bed will not produce a complete X-ray picture of all the nodes in a given region in live subjects.

Application of the X-ray method in living persons, however, reveals lymph routes that can not be detected in cadavers or can be detected only with great difficulty. Using this method, for instance, scientists have determined that the lymphatic vessels of the perineum pass not only to the pelvic and lumbar lymph nodes, but to the nodes of the armpit, stretching along all the lateral surface of the trunk. Consequently not only the pelvic and lumbar nodes but the axillary nodes as well are regional lymph nodes of the perineum.

A special apparatus called the kymograph makes it possible to judge the efficacy of lymph circulation. Using the kymograph it is possible to observe the contraction of the large lymphatic ducts (pulsation) in a series of photographs and to check the velocity at which lymph flows.

Thus, the roentgenological method offers a number of advantages for studying the lymphatic system since it makes it possible to study the system directly on the living human body without disrupting natural anatomical relationships, which is inevitable in dissection. Roentgenolymphography also makes it possible to study the relationship of the lymphatic bed to the bones (skeletopy) and to the blood vessels, if vasography (syntopy) is performed simultaneously with the projection of the large lymphatic ducts and nodes on the skin (holotopy).

The development of lymphatic vessels

The development of the lymphatic system in the process of phylogenesis is closely related to the development of blood circulation, which, in turn, is determined by the adaptation of the respiratory organs to the environment.

In aquatic fauna (**fish** which breathe with gills and have a dual-chamber venous heart), lymph is propelled by the pulsations of the lymphatic heart, a dilated lympthatic vessels propels lymph into the venous bed. **Fish** have **no lymph nodes**, and the lymphatic tissue is diffuse. In **amphibians** the number of lymphatic hearts increases, and they are situated in pairs on the border between the trunk and the extremities (anterior and posterior pairs). The diffuse lymphatic tissue becomes concentrated in follicles located in the mucous membranes.

When gills are finally replaced by lungs in terrestrial animals and pulmonary circulation develops in addition to systemic circulation, the movement of lymph is facilitated by the throbbing of the heart. As a result the role of lymphatic hearts diminishes, and they gradually disappear to be preserved only in a single (posterior) pair. At the same time the several number of lymphatic vessels increases.

In **birds** lymphatic hearts are present only in the foetus, and the number of lymphatic vessels increases. Valves appear inside the vessels, preventing the reverse flow of lymphatici. Several lymph nodes make their appearance. With the appearance of a muscular diabragm in mammals and the further development of the heart and blood vessels as well as the skeletal musculature, the movement of lymph is eased by the suction action of the thoracic cage and the contraction of the heart, blood vessels, and muscles. There is no longer any need for the lymphatic hearts, and they disappear completely. At the same time, he number of lymphatic vessels, in which many valves develop, increases. The lymph ducts passing along the aorta merge into a large unpaired trunk, the ductus thoracicus. The number of lymph nodes increases sharply, particularly in primates.

Since **human** beings walk erect, the number of valves in the lymphatic vessels of human extremities increases, particularly in the lower limbs. Humans have the greatest number of lymph nodes of any species, which testifies to the increased importance of the lymphatic system in limiting the spread of pathological processes.

There are **two theories** regarding the embryonic development of the lymphatic system. According to the **centrifugal** development theory, as the first theory is called, the lymphatic system develops out of the venous system. The second theory contends that the system originates separately out of the **mesenchyme** and only later joins the veins; this theory is called the theory of **centripetal** development. Most authors currently recognize the latter theory, according to which the lymphatic system develops independently of the system of blood circulation and establishes connections with the venous system secondarily. The lymphatic system originates as detached germs, which grow, branch out, and form canals, tr lymph capillaries. Expanding and merging, these capillaries, in their second month, form six lymph sacs: two by the jugular veins, one retroperitoneal at the base of the mesentery, near the adrenals, one neighbouring the preceding one (this is the **cisterna chyli**), and two by the iliac veins.

The lymphatic vessels of the head, neck, and upper extremity (these last from supplementary sacs occurring by the subclavian veins) develop from jugular sacs. The **retroperitoneal sac** gives rise to vessels of the mesentery collecting lymph from the intestine. The **iliac sacs** are the source for vessels of the lower limbs and pelvis. Moreover, the **jugular sacs** grow in the direction of the thoracic cavity and join in a single trunk, which meets the growing cisterna chyli. As a result a thoracic duct uniting the systems of the iliac, retroperitoneal and jugular sacs is formed. Thus, a single system of lymphatic vessels is created, which makes contact with the venous system only near the jugular sacs at the confluence of the jugular and subclavian veins on both sides of the body.

The initially symmetrical structure of the lymphatic system is disturbed later, however, because the left duct (thoracic) develops to a greater extent than the right. This greater development is explained by the asymmetrical position of the heart and large veins which creates more favourable conditions for the flow of lymph and blood through the left side in the region of the left venous angle. On the right side, because of the proximity to the venous half of the heart, there is a greater periodical increase of pressure in the vena cava superior as the result of heart contractions, which hampers the stream of lymph from freely joining the flow of venous blood. This functional difference in the circulation through the right and left main lymph trunks of the body also explains their unequal development. A dual thoracic duct, common in lower vertebrates, is sometimes preserved as a developmental variant in humans. Besides the lymphatic vessels and sacs, the lymph nodes also develop, but somewhat later (in the third month).

Immune system

For growing up, development and accommodation to all changes of external and internal environment, the body is permanently fighting with microorganisms and its produced poisons .

To maintain this equilibrium is duty of ***immune system.***

Some terms used in imunology

- **Immunity** – protection of body against genetic foreign structures.
- **Immune System** – is the sum of all organs and tissue that maintain the genetic homeostasis (stability) of body, protecting against macro organism from microorganisms, tumor cells, non-self cells (foreign).
- Functional control is realized by neuro- humoral, paracrine and autocrine mechanisms.

There are 2 main mechanisms of immunity:

- Nonspecific –standard answer against foreign invasion
- Specific – defense answer pointed précis to special pathogen agent

The activity of the Immune System is executed by **cells** and it’s **secretes**.

- **In Nonspecific Immunity:**
  - Neutrophils
  - Monocytes

- Macrophages
- Natural killer cells (NK)
- **In Specific Immunity:**
  - T Limphocyts
  - B Limphocyts

The blood cells develop from stem cells in the red bone marrow. After originating in the marrow, part of the cells develop further in the thymus. This is why the bone marrow and thymus are considered central organs. Many subsequent cellular transformations on the way to specialized forms take place in the lymph nodes, tonsils, spleen and other lymphoid organs, which are, therefore, considered peripheral organs of haemopoiesis and immun reactions.

Classification of immune system organs

- Central Organs
  - Bone marrow (red and yellow)
  - Tymus
- Peripheral Organs
  - Lymph nodes
  - Spleen
  - Lymphoid tissue (associated with mucosa of tubular organs - MALT) of:
- – Digestive System (GALT)
  - » pharynx (ring of Waldayer)
  - » small and large intestine (solitary and aggregate lymph follicles, vermiform appendix)
- – Respirator System (BALT)
- – Urogenital Apparatus

Central organs of immune system organs

Bone marrow

- There are:
  - – Red bone marrow
  - – Yellow bone marrow
- Red bone marrow give rise for cells:
  - – myeloid line cells (erythrocytes, white blood cells, trombocytes)
  - – lymphoid line cells (lymphocytes)

Red bone marrow, is typically found within the trabecular cavities of spongy bone of long bones and in the diploë of flat bones. For this reason, both these cavities are often referred to as red marrow cavities. In newborn infants, the medullary cavity of the diaphysis and all areas of spongy bone containred bone marrow. In most adult long bones, the fat-containing medullary cavity extends well into the epiphysis, and little redmarrow is present in the spongy bone cavities. Hence, blood cell production in adult long bones routinely occurs only in the heads of the femur and humerus (the long bone of the arm). The red marrow found in the diploë of flat bones bones (such as the sternum) and in some irregular bones (such as the hip bone) is much more active in hematopoiesis, and these are the sites routinely used for obtaining red-marrow samples when problems with the blood-forming tissue are suspected. However, **yellow marrow** in the medullary cavity **can revert to red marrow** if a person becomes very anemic and needs enhanced red blood cell production.

The thymus

The thymus (thymus) is located in the upper anterior part of the thoracic cavity behind the manubrium sterni and part of the sternum body. It consists of two lobes (**lobi dexter** and **sinister**), which are connected by loose connective tissue. The narrower, upper ends of the lobes usually stretch beyond the border of the thoracic cage; they protrude over the upper edge of the manubrium sterni, sometimes reaching the thyroid gland. Widening toward its base the thymus settles in front of the major cardiac vessels and part of the pericardium. The size of the gland changes with age. In the newborn it weighs about 1,2 grams and continues to grow after birth until puberty when it weighs from 35 to 40 grams. After puberty (14-15 years), the process of involution begins, as a result of which the weight of the thymus reduces. At the age of about 25, the thymus weighs 25 grams. At 60, it weighs less than 15 grams, and at 70 it weighs about 6 grams. The lateral parts of the gland as well as some of the lower areas atrophy so the gland in adults is elongated. In involution the elements of the gland are replaced, to a considerable degree, by fatty tissue, while the general outlines of the gland are preserved.

Topography. **In children** the gland projects skeletopically at the top 1 to 1,5 cm over the manubrium sterni. Its lower end reaches the third, fourth, and, sometimes, fifth rib. **In adults**, as a rule, the neck of the gland is absent, and its top edge lies behind and at various distances below the notch of the manubrium sterni. The lower edge corresponds to the second intercostal space or the third rib.

The syntopy of the gland is different in children and in adults. In infants under three years of age, the neck of the gland lies behind the sternothyroid and sternohyoglossus muscles. Its posterior surface lies close to the trachea, and the thoracic section of its anterior surface lies close to the surface of the sternum. The inferior surface of the gland lies immediately proximate to the pericardium; the posterior surface adjoins the large vessels. The right and left anterolateral surfaces are covered with pleura. If the manubrium sterni is removed in adults, tissue containing glandular remnants of various size can be seen. In front the gland is covered with layers of connective tissue, which, continuing the fasciae of the neck, join with the pericardium below.

Structure. The thymus is covered by a thin connective tissue **capsule** from which **septa** grow into the gland. These septa divide the gland into **lobules** consisting of a **cortical** (darker) **substance** and a **medullary substance**. The cortical substance consists of tissue formed by a retinaculum of epithelial cells in the loops of which are lymphoid elements, the lymphocytes of the thymus (thymocytes). They form accumulations similar to the follicles of the lymph nodes. Concentric nests called **corpuscles of the thymus or Hassall's corpuscles** are scattered throughout the medullary substance.

Development. The epithelial part of the thymus develops as an outgrowth of the prechordal plate in the region of the **third pharyngeal** pouch. All its derivatives have many of the same properties as the epidermis of the skin. The lymphocytes develop from the blood cells of the trunk, into which they drain from various blood vessels.

Function. In the thymus special lymphocytes called **T-lymphocytes** acquire certain properties which enable them to react defensively against cells that, for various reasons, have become foreign to the organism. The early loss of the thymus function leads to the impairment of the immunological system. The epithelial cells of the lobules secrete a hormone (thimolin, thimozin, thimopoiethin) which regulates the conversion of lymphocytes in the thymus itself..

The **arteries** to the gland branch off from a. thoracica interns, the truncus brachiocephalicus, and a. subclavia. The **veins** drain into v. brachiocephalica sinistra and also into v. thoracica interns. Numerous lymphatic vessels accompany the blood trunks and end in the nearest lymph nodes of the mediastinum. **Innervation** is received from tr. sympathicus and n. vagus as well as from the cervical spinal nerves.

Peripheral organs of immune system organs

The lymph nodes

The lymph nodes also belong to the group of organs of haemopoiesis, immunological reactions and lymphatic organs.

The spleen

The **spleen**, (lien) (Gk splen) is a richly vascularized, lymphoid organ (some scientists consider the spleen as a lymph node located along the route of a blood vessel). The blood system in the spleen is closely tied to the lymphoid tissue since blood is enriched here with a fresh reserve of leukocytes developed in the spleen. Moreover, the phagocytic activity of the spleen's macrophages frees blood passing through the spleen of red blood cells ("cemetery" of erythrocytes), pathogenic microbes, suspended foreign particles, and so on.

The size of the spleen may change considerably even within a single individual because the spleen has so many blood vessels which may be filled with various quantities of blood. On the average, the spleen is 12 centimetres long, 8 centimetres wide, and 3-4 centimetres thick and weighs about 170 grams (from 100 grams to 200 grams). During digestion the spleen becomes larger. The surface of the spleen is dark red with shades of violet.

The shape of the spleen is often compared to a coffee bean. **Two surfaces** are distinguished in the spleen (the **facies diaphragmatica** and **facies visceralis**), **two margins** (anterior and posterior), and **two ends** (superior and inferior). The most extensive surface facing the lateral side, the facies diaphragmatica, is convex and adjoins the diaphragm. On the visceral concave surface, in, the region adjoining the stomach (**facies gastrica**), lies a longitudinal groove, **hilus** or porta lienis - the hilum through which vessels and nerves enter the spleen. Posteriorly of the facies gastrica is a longitudinally situated flat area; this is the facies renalis, so called because here the spleen adjoins the left adrenal gland and kidney. The inferior end of the spleen, contiguous with the colon and **lig. phrenicocolicum**, is the **facies colica**.

Topography. The spleen is located in the left hypochondrium at a level from the ninth to the eleventh rib. The long axis of the spleen is directed from top to bottom, outward, and somewhat forward, nearly parallel to the posterior segments of the lower ribs. A spleen is high if its superior pole reaches the eighth rib (brachymorphic constitution) and low if its superior pole is below the ninth rib (dolichomorphic constitution). The peritoneum. grows together with the splenic capsule and covers it completely except at the porta where the peritoneum bends onto the vessels and passes over to the stomach, forming **lig. gastrolienale**. Lig. phrenicolienale, a fold of the peritoneum (which is sometimes absent), passes from the porta of the spleen to the diaphragm near the entrance of the oesophagus. In addition, in the region of the eleventh left rib, lig. phrenicocolicum, which stretches between the colon transversum and the lateral wall of the abdomen, forms a sort of pocket for the spleen, which rests against this ligament with its lower end.

Structure. Besides its **serous coat** the spleen has its own connective tissue capsule, tunica fibrosa, with an admixture of elastic and smooth muscle fibres. The capsule continues into the thickness of the organ in the form of braces, particularly distinct near the porta. The **trabeculae** and connective tissue, which penetrated the thickness of the organ with the vessels, branch out, and winding and joining with one another, frame the spleen and divide it into separate parts. Between the trabeculae is splenic pulp, **dark red** in colour **red pulp.** In fresh dissections nodes that are lighter in colour than the pulp are visible: these are Malpighian bodies, or corpuscles white pulp, which are round or oval lymphoid formations, about 0.36 mm in diameter, clinging to the walls of small arterial branches. The pulp consists of reticular tissue, the loops of which are filled with different cellular elements, lymphocytes, leukocytes, and red blood corpuscles (most of which have already disintegrated) with grains of pigment.

Function. Lymphocytes participating in immunological reactions are contained in the lymphoid tissue of the spleen. Part of the formed elements of the blood, which have exhausted their usefulness, die in the red pulp. The iron of the haemoglobin of the disintegrated erythrocytes is channelled along the veins to the liver where it serves as material for the synthesis of bile pigments.

Vessels and nerves. The **splenic artery** is remarkable for its large diameter to the size of the organ itself. Near the porta the artery spreads out into six or eight branches, each of which enters the organ separately where they, in turn, give rise to tiny branches called **penicillin arteries** which group together like brushes. The arterial capillaries develop into venous sinuses, the walls of which are formed by the endothelial syncytium with numerous fissures through which the blood elements pass to the venous sinuses (**open blood circulation**). In distinction from the tiny arterial trunci, the venous trunci arising here form numerous anastomoses with one another. The roots of the splenic vein (veins of the 1st order) carry blood from relatively isolated areas of the parenchyma of the organ.

There are from two to four zones in the venous bed of the spleen, but most often there are three (anterior, middle, and posterior zones). The number of segments varies more widely, from five to seventeen. Most commonly the venous bed consists of eight segments. Depending on their position in the organ they may be designated as anterior polar, anterior upper, anterior lower, middle upper, middle lower, posterior upper, posterior lower and posterior polar segments.

The number, size, and position of the zones and segments, and the direction of the small vascular borders dividing them have a certain correlation with the shape of the spleen.

The splenic vein drains **into v. portae**. There are **no lymph vessels in the pulp**. The nerves from the plexus celiacus penetrate together with the splenic artery.

Development. The spleen is laid down in the mesogastrium posterius in the form of accumulation of cells of the mesenchyma in the fifth week of intrauterine life. In newborns the spleen is relatively large (10-15 grams). After the age of 40 a gradual decrease of the spleen becomes noticeable.

The tonsils

The tonsils are the simplest lymphoid organs. They form a ring of lymphatic tissue around the entrance to the pharynx (throat), where they appear as swellings of the mucosa. The tonsils are named according to location. The paired **palatine tonsils** are located on either side at the posterior end of the oral cavity. These are the largest of the tonsils and the ones most often infected. A lumpy collection of lymphoid follicles at the base of the tongue is referred to collectively as the **lingual tonsil**. The **pharyngeal tonsil** (referred to as the adenoids if enlarged) is in the posterior wall of the nasopharynx. The tiny **tubal tonsils** surround the openings of the auditory tubes into the pharynx. The tonsils gather and remove many of the pathogens entering the pharynx in food or in inhaled air.

The lymphoid tissue of the tonsils contains follicles with obvious germinal centers surrounded by diffusely scattered lymphocytes. The tonsils are not fully encapsulated, and the epithelium overlying them invaginates deep into their interior, forming blind-ended tonsillar crypts. The crypts trap bacteria and particulate matter, and the bacteria work their way through the mucosal epithelium into the lymphoid tissue, where most are destroyed. It seems a bit dangerous to "invite" infection this way, but this strategy produces a wide variety of immune cells that have a "memory" for the trapped pathogens. Thus, the body takes a calculated risk early on (during childhood) for the benefits of heightened immunity and better health later.

Aggregates of lymphoid follicles

Peyer's patches are large isolated clusters of lymphoid follicles, structurally similar to the tonsils, that are located in the wall of the distal portion of the small intestine. Lymphoid follicles are also heavily concentrated in the wall of the appendix, a tubular offshoot of the first part of the large intestine. Peyer's patches and the appendix are in an ideal position (1) to destroy bacteria (which are present in large numbers in the intestine), thereby preventing these pathogens from breaching the intestinal wall, and (2) to generate many "memory" lymphocytes for long-term immunity. Peyer's patches, the appendix, and the tonsils—all located in the digestive tract—and lymphoid follicles in the walls of the bronchi (organs of the respiratory tract) and in the mucosa of genitourinary organs, are part of the collection of small lymphoid tissues referred to as mucosa-associated lymphatic tissue (MALT). MALT protects passages that are open to the exterior from the never-ending onslaughts of foreign matter entering them.

NEUROLOGY

General data

One of the most important characteristics of living substances is their capacity to respond to stimuli. Every living organism receives stimuli from external and internal environments and responds to such stimuli by corresponding reactions which link the organism to the environments. Metabolic processes within the organism itself, in turn, create a number of stimuli to which the organism must also react. In higher multicellular organisms the area receiving the stimulus and the reacting organ are connected by the nervous system.

Branching into all the organs and tissues, the nervous system binds and integrates all parts of the organism into a single, whole body.

The activity of the nervous system is based on the reflex (I.M. Sechenov). "This means that a nervous receptor receives a signal from an agent of the external or internal world of the organism. This signal is transformed into a nerve process, in a phenomenon of nervous stimulation - nerve impulse. The nerve impulse passes along nerve fibres, as along wires, to the central nervous system and, from there, along established connections of other wires to the organ itself where it is transformed, in turn, into a specific action of the cells of this organ" (Pavlov).

The basic anatomical element of the nervous system is the nerve cell which, together with all the processes arising from it, is called the **neuron**. A long axial cylindrical process, called the **axon** or **neurite**, arises from the body of the cell in one direction. Short branched processes called **dendrites** lead in the other direction.

Nervous impulse inside the neuron flows from the dendrites to the cell body and from there to the axon; the axons convey the nervous impulse away from the cell body. The conduct of the nerve impulse from one neuron to another is accomplished by means of specially built end apparatuses or **synapses** (Gk synaptein to join). Axo-somatic connections of neurons in which the branches of one neuron approach the cell body of another neuron, can also be distinguished, as can axo-dendritic connections in which contact is accomplished by the dendrites of nerve cells. These latter are phylogenetically younger and are highly developed in the upper layers of the cortex, which are also phylogenetically more recent and functionally more sophisticated. These axodendritic connections play a role in the redistribution of nerve impulses in the cortex and evidently represent the morphological basis of temporary connections in conditioned-reflex activity. Axo-somatic connections prevail in the spinal cord and subcortical formations.

The intermittent flow of nerve conduction throughout the body allows for a great variety of connections. Thus, the nervous system is composed of a complex of neurons which come into contact with one another but never grow together. Consequently, the nervous impulse that arises in one part of the body is conveyed along the processes of nerve cells from one neuron to a second, from there to a third, and so on. A clear example of the connection established between organs through the neurons is the reflex arc which forms the basis of the reflex, the simplest and at the same time most fundamental reaction of the nervous system.

The simple reflex arc consists of at least two neurons, one of which connects with a sensory surface (the skin, for instance) and the other, which, with its axon, ends in a muscle (or a gland). When the sensory surface is stimulated, the nervous impulse passes centripetally along the neuron connected to it to the reflex centre where the synapse of both neurons is located. Here the nervous impulse is transferred to the other neuron and directed centrifugally to the muscle or gland. As a result the muscle contracts or the secretion of the gland changes. Quite often a third interneuron, which serves as a transmitting station from the sensory route to the motor route, is included in the simple reflex arc.

The simple reflex arch is closed at level of one medullar or cerebral segment.

Besides the simple (three-member) reflex arc there are complex multineuronal reflex arces passing through different levels of the brain, including the cerebral cortex. In man and other higher animals neurons also form temporary reflex connections of the highest order on the basis of simple and complex reflexes. These temporary reflex connections are known as conditioned reflexes (Pavlov).

Thus, the elements of the nervous system may be classified as one of three kinds according to function.

Receptors transform the energy of the external stimulus into a nerve impulse; the receptors are connected with afferent (centripetal or receptor) neurons, which transmit the triggered excitation (nerve impulse) toward the centre; the analysis begins from this event.

Conductors are internuncial or connecting neurons which accomplish the contact, i.e. the transfer of the nerve impulse from the centripetal to the centrifugal neuron and the transformation of the impulse received by the centre into an external reaction. This synthesis evidently represents the phenomenon of the nerve connector.

Efferent (centrifugal) neurons implement response reactions (motor or secretory) by conducting the nervous impulse from the centre to the effector (the producer of the effect or the action) at the periphery, i.e. to the working organ (muscle, gland). This is why this neuron is also called the **effector neuron**.

The receptors are stimulated by three sensory surfaces, or receptor fields, of the organism:

1. extero-receptors (exteroceptive field) receive stimuli from the external environment - the external skin surface of the body contact receptors and through the sense organs which are genetically related to the skin telereceptors;

2. interoreceptors (interoceptive field) receive stimuli from the internal surfaces of the body stimulated mostly by chemical substances entering the internal cavities, glands, vessels;

3. (proprioceptive fields) the thickness of the walls of the body itself where the bones, muscles, and other organs are laid out and produce stimuli received by special receptors. The receptors from such fields are connected with afferent neurons which reach the centre and transfer there to various efferent conductors by a very complicated system of conductors. These efferent conductors produce various effects in conjunction with the working organs. Besides the reflex arc, a reflex circle has been found recently which participates as a basic component of nervous system activity.

Modern cybernetics has established the common feedback principle of connections in the control and coordination of processes in both modern automatons and living organisms. From this viewpoint a feedback connection can be distinguished in the nervous system between the working organ and the nerve centers. This phenomenon called feedback afferentation involves the transmission of impulses about the activity of the organ at any given moment from the working organ to the central nervous system. When the centres of the nervous system send efferent impulses to the executive organ, certain actions (movement, secretion) are triggered in this organ. These actions, in turn, stimulate nervous (sensory) impulses which return along afferent routes to the spinal cord and brain signalling that a certain action has just been performed by the working organ. Thus, the essence of feedback afferentation, is, figuratively speaking, a report to the centre that its command has been fulfilled by the periphery.

When the hand reaches for an object, for example, the eyes constantly measure the distance between the hand and the object and dispatch the information as afferent signals to the brain. A contact is made in the brain with efferent neurons which convey motor impulses to the muscles of the hand reaching for the object. At the same time the muscles act upon the receptors within them to transmit continuous sensitive signals to the brain and thus report on the position of the hand at every moment. This two-way signalization along the reflex circuits continues until the distance between the hand and the object is reduced to zero, i.e. until the hand grasps the object. The action of the working organ is thus constantly self-controlled by the mechanism of feedback afferentation, which functions as a closed circuit in the following succession: from the centre (the instrument setting the programme of action) to the effector (motor) to the tool (working organ) to the receptor (receiver) and back to the centre.

Such a closed circuit of reflexes in the central nervous system guarantees all the complex correction of the processes taking place in the organism no matter what changes may occur in the internal and external environment. Without the feedback mechanism living organisms would fail to adapt reasonably to the environment. Thus, in addition to the disconnected reflex arc which forms the basis of the nervous system, there are the closed reflex circuits that facilitate feedback afferentation of the working organ with the centres of the nervous system and that explain the reflex coordination of all its activity.

The unified human nervous system is conditionally divided into two parts corresponding to the two principal parts of the organism —vegetative and animal:

(1) The vegetative nervous system innervates the internal organs, the endocrine system, and the smooth muscles of the skin, heart, and vessels, i.e. the organs of vegetative life which create the internal media of the organism; the vegetative nervous system is sometimes called both **autonomous** (athough a certain amount of autonomy is enjoyed by the spinal cord) and **visceral**, although vegetative innervation is not limited to the internal organs.

(2) The animal nervous system controls the striated musculature of the skeleton and certain internal organs (tongue, larynx, pharynx) and primarily innervates the organs of animal life. The animal nervous system is also called the **somatic system,** meaning soma, i.e. the body itself. For the most part it controls the functions connecting the organism with the environment, provides the sensitivity of the organism (through the sense organs), and the movements of the muscles of the skeleton.

The vegetative part of the nervous system is, in turn, divided into the **sympathetic** and **parasympathetic** systems. The former system innervates the entire body while the parasympathetic system innervates only certain parts of it.

In addition to this structural classification the nervous system can be classified topographically into **central** and **peripheral** systems.

The central nervous system consists of the spinal cord and brain made up of grey and white matter; **the peripheral system** includes all other components, i.e. the nerve roots, ganglia, plexuses, nerves, and peripheral nerve endings.

Both the central and peripheral parts of the nervous system contain elements of its animal and vegetative components, thus uniting the nervous system as a whole. Its most highly developed section, which controls all the processes in the body, both animal and vegetative, is the cortex of the brain.

The peripheral nervous system

Animal, or Somatic, Nerves

The nerve trunks are divided according to the place where they branch off from the central nervous system: **the spinal nerves** (nn. spinales) branch off from the spinal cord while **the cranial nerves** (nn. craniales) arise from the brain.

The spinal nerves

The spinal nerves (nn. spinales) are located in regular order (neuromeres) corresponding to the myotomes (myomeres) of the trunk and alternate with the segments of the spine; every nerve is attended by a corresponding area of skin (dermatome).

Man has **31 pairs** of spinal nerves: 8 pairs of cervical, 12 pairs of thoracic, 5 pairs of lumbar, 5 pairs of sacral and 1 pair of coccygeal nerves. Every **spinal nerve** branches off from the spinal cord in two roots: **the**

dorsal or posterior (sensory) **root**, and **the ventral** or anterior (motor) **root**. Both roots are joined in **one trunk**, which passes from the spine through an intervertebral orifice. Near and somewhat externally of the place where the roots join, the posterior root forms the **ganglion spinale** or ganglion intervertebrale in which the anterior motor root does not participate. Since both roots are joined the spinal nerves are mixed nerves; they contain **sensory** (afferent) fibres from the cells of **the spinal ganglia**, **motor** (efferent) fibres from the cells of **the anterior horn**, and also **vegetative** fibres from the cells of **the lateral horns** emerging from the spinal cord as part of the anterior root.

The vegetative fibers which pass through the roots into the animal neuritis ensure such processes in the soma as trophies, vasculomotor reactions, etc.

In primal fishes both roots continue into separate nerves, motor and sensory. In the further progress of evolution the nerves converge and merge so that the separate passage is preserved only for the roots, while the nerves become mixed.

On emerging from the intervertebral orifice every cerebrospinal nerve divides, according to two parts of the myotome (dorsal and ventral), into two branches:

1. **the posterior, dorsal branch** (ramus dorsalis) for the autochthonous muscles of the back developing from the dorsal part of the myotome and the skin covering it;

2. **the anterior, ventral branch** (ramus ventralis) for the ventral wall of the trunk and the limbs, developing from the ventral parts of the myotomes.

Besides this, other two kinds of branches arise from the cerebrospinal nerve:

3. **the communicating branches** (rami communicantes) to the sympathetic trunk for innervating the internal organs;

4. **the meningeal branch** (ramus meningeus) passing back through the intervertebral orifice for innervating the membranes of the spinal cord.

The posterior branches of the spinal nerves

The posterior branches (rami dorsales) of all the cerebrospinal nerves pass backward between the transverse processes of the vertebrae, curving around their articular processes. With the exception of the **first** cervical, **fourth** and **fifth** sacral and coccygeal branches, they all divide into **the medial branch** (ramus medialis) and **lateral branch** (ramus lateralis) which supply the skin of the back of the head, the posterior surface of the neck and back and the deep dorsal muscles.

The posterior branch of **the first cervical nerve**, **n. suboccipitalis**, emerges between the occipital bone and the atlas and then divides into branches supplying **mm. recti capitis major and minor**, **m. semispinalis capitis, mm. obliqui capitis.** N. suboccipitalis does not give off branches to the skin.

The posterior branch of **the second cervical nerve**, **the greater occipital nerve** (n. occipitalis major) coming out between the posterior arch of the atlas and the second vertebra, pierces the muscles and, having become subcutaneous, innervates the occipital part of the head.

Rami dorsales of **the thoracic nerves** divide into **medial** and **lateral branches** giving rise to branched running to the autochthonous muscles; the skin branches of the superior thoracic nerves originate only from rami mediales, while those of the inferior thoracic nerves, from rami laterales.

The cutaneous branches of the **three upper lumbar nerves** pass to the superior part of the gluteal region under the name of gluteal branches (of the posterior primary rami of lumbar nerves) **(nn. clunium superiores)**; the cutaneous branches of the **sacral nerves** are called gluteal branches (of the posterior primary rami of sacral nerves) **(nn. clunium medii**).

The anterior branches of the spinal nerves

The anterior branches (rami ventrales) of the spinal nerves innervate the skin and muscles of the ventral wall of the body and both pairs of limbs. Since the skin of the lower abdomen participates in the development of the external sexual organs, the skin covering them is also innervated by the anterior branches. Except for the first two, the anterior branches are much larger than the posterior branches.

The anterior branches of the spinal nerves preserve their original metameric structure only in **the thoracic segment** (**nn. intercostales**). In the other segments connected with the limbs in whose development the segmentary character is lost, the nerves arising from the anterior spinal branches intertwine. This is how **nervous plexuses** are formed in which exchange of fibres of different neuromeres takes place. A complex redistribution of fibres occurs in the plexuses: the anterior branch of every spinal nerve sends its fibres into several peripheral nerves and, consequently, each of them contains fibres of several segments of the spinal cord. It is therefore understandable that lesion of a nerve arising from the plexus is not attended by disturbed function of all the muscles receiving innervations from the segments which gave origin to this nerve.

Most of the nerves emerging from plexuses are mixed; this is why the clinical picture of the lesion is made up of motor disorders, sensory disorders and vegetative disorders.

Three large plexuses are distinguished: **cervical, brachial** and **lumbar, sacral, coccigeal (lumbosacral or lunbosarococigeal)**.

The cervical plexus

The cervical plexus (plexus cervicalis) is formed by the anterior branches of **four superior cervical nerves** (C1-C4) which are connected by three arching loops and are located laterally of the transverse processes between the prevertebral muscles from the medial side and vertebral (m. scalenus medius, m. levator scapulae and m. splenius cervicis) from the lateral side, anastomosing with n. accessories (XI cranial nerve), n. hypoglossus (XII cranial nerve) and tr. sympathicus. In front the plexus is covered by m. sternocleidomastoideus.

The branches arising from the plexus are divided into cutaneous, muscular and mixed.

The skin branches:

1. **The lesser occipital nerve** (n. occipitalis minor) (from C2 and C3) runs to the skin of the lateral part of the occipital region.

2. **The great auricular nerve** (n. auricularis magnus) (from C3), the thickest nerve of the cutaneous branches of the cervical plexus, passes to the concha auriculae, supplying it and the external acoustic meatus.

3. **The transverse nerve of the neck** (n. transversus colli) (from C2-C3) arises, like the preceding two nerves, from the middle of the posterior edge of m. sternocleidomastoideus and divides into branches which curve around the posterior edge of the sternocleidomastoid muscle and pass over its external surface forward and down under the m. platysma, supplying the skin of the neck.

4. **The supraclavicular nerves** (nn. supraclaviculares) (from C3 and C4) descend under the platysma nearly perpendicularly along the supraclavicular fossa into the skin above the pectoralis major and deltoideus). We distinguish **medial, intermedial,** and **lateral supraclavicular nerves** where each of them is responsible for corresponding area over the clavicle.

The muscular branches:

1. Branches to the mm. recti capitis anterior and lateralis, mm. longus capitis and colli, mm. scaleni, m. levator scapulae and, finally, to mm. intertransversarii anteriores.

2. Radix inferior, arising from C2-C3, passes in front of the v. jugularis interna under the sternocleidomastoid muscle and at the intermediary tendon of the m. omohyoideus joins with radix superior coming from **hypoglossal nerve** (C1), forming a **cervical loop** (ansa cervicalis) with this branch. By means of the branches arising from the ansa, the fibres of the cervical plexus innervate the m. sternohyoideus, m. sternothyreoideus and m. omohyoideus.

3. Branches to the m. sternocleidomastoideus and m. trapezius (from C3 to C4) which participate in the innervation of these muscles together with the **accessory nerve**.

The mixed branches:

The phrenic nerve (n. phrenicus) (C3-C4) descends along m. scalenus anterior into the thoracic cavity where it passes between the subclavian artery and vein. Further **the right phrenic nerve** descends nearly vertically in front of the root of the right lung and passes along the lateral surface of the pericardium to the diaphragm. **The left phrenic nerve** crosses the anterior surface of the aortic arch and passes in front of the root of the left lung along the left lateral surface of the pericardium to the diaphragm. Both nerves pass in the anterior mediastinum between the pericardium and pleura. The phrenic nerve receives fibres from two inferior cervical ganglia of the sympathetic trunk. The phrenic nerve is a mixed nerve: its **motor branches innervate the diaphragm** thus functioning as a nerve that is responsible for respiration; it sends **sensory nerves to the pleura and pericardium.** Some of the terminal branches of the nerve pass through the diaphragm into the abdominal cavity (nn. phrenicoabdominales) and anastomose with the sympathetic plexus of the diaphragm, sending small branches **to the peritoneum**, **the hepatic ligaments** and **to the liver** itself; as a result, when liver is affected, a special phrenicus-symptom may arise. There are informations indicating to wider innervation by the phrenic nerve; it is supposed that with its fibres in the thoracic cavity it supplies the heart, lungs, the thymus gland, and in the peritoneal cavity it is connected with the solar plexus through which it innervates certain internal organs.

The brachial plexus

The brachial plexus (plexus brachialis) is composed of the anterior branches of four inferior cervical nerves (C5-C8) and the greater part of first thoracic nerve (Th1); it is often joined by a thin branch from C4. The brachial plexus passes through the space between the scalenus anterior and scalenus medius muscles into the supraclavicular fossa, interscalenic space, higher and behind the subclävian artery.

The most common arrangement of the brachial plexus is as follows: the **fifth** and **sixth** rami unite at the lateral border of scalenus medius as **the upper trunk;** the **eighth** cervical and **first thoracic** rami join behind scalenus anterior as **the lower trunk**; the **seventh** cervical ramus becomes **the middle trunk**. The three trunks incline laterally, and either just above or behind the clavicle (**pars supraclavicularis)** each bifurcates into **anterior** and **posterior** divisions.

The anterior divisions of the upper and middle trunks form **a lateral cord** that lies lateral to the axillary artery. The anterior division of the lower trunk descends at first behind and then medial to the axillary artery and forms **the medial cord**, which often receives a branch from the seventh cervical ramus. **Posterior divisions** of **all three trunks form the posterior cord**, which is at first above and then behind the axillary artery.

These entire three thick nerve trunks (cords) pass into the axillary fossa and surround a. axillaris from three sides and are named as **pars infraclavicularis**.

There are **short** and **long** peripheral branches.

The short branches arise from various points in **the supraclavicular part** of the plexus and supply the cervical muscles partially, as well as the muscles of the shoulder girdle (with the exception of m. trapezius) and the shoulder joint.

The long branches arise from the above mentioned three trunks and run the length of the upper limb, innervating its muscles and skin.

The short branches:

- The **lateral** pectoral nerves **(n. pectoralis lateralis**) (from C5-C7) run to both mm. pectoralis (major and minor) from the **lateral** cord.
- The **medial** pectoral nerves **(n. pectoralis medialis**) (from C8-Th1) run to both mm. pectoralis (major and minor) from the **nedial** cord.
- **The suprascapular nerve** (n. suprascapularis) (from C5 and C6) passes through the incisura scapulae into the fossa supraspinata and together with a. suprascapularis passes under the acromion into the infraspinous fossa. It innervates mm. supra- and infraspinatus and the capsule of the shoulder joint.
- **Superior subscapular nerve** (n. subscapulares superioris) (C5-C6) supply (the same name muscle) m. subscapularis (upper part). **Inferior subscapular nerve** (n. subscapulares inferioris) (C5-C6) supply m. subscapularis (lower part), m. teres major (could be a separate branch for this muscle).
- **The dorsal scapular nerve** (n. dorsalis scapulae) (from C5) accompanies the descending branch of a. transversa colli (a. dorsalis scapulae) along the medial edge of the shoulder blade. It innervates m. levator scapulae and mm. rhomboidei (major et minor).
- **The thoracodorsal nerve** (n. thoracodorsalis) (C6-C8) running along the axillary edge of the shoulder blade together with subscapular artery to m. latissimus dorsi.
- **The long thoracic nerve** (n. thoracicus longus) (from C5-C7) descends along the external surface of m. serratus anterior, which it supplies. (the longest). It usually arises by three roots from the fifth, sixth, and seventh cervical nerves; but the root from the seventh nerve may be absent.
- The nerve to the subclavius muscle **(n. subclavius**) (C5) passes to m. subclavius. (the smallest)

- **The axillar nerve** (n. axillaris) (circumflex nerve) (from C5-C6) is **the thickest** nerve among the short branches of the brachial plexus, a branch of **the posterior trunk** of the brachial plexus.. It passes together with **a. circumflexa humeri posterior** through the **foramen quadrilaterum** onto the posterior surface of the surgical neck of the humerus and sends branches to mm. deltoideus (**anterior branch**), teres minor and to the capsule of the shoulder joint (**posterior branch**). Along the posterior edge of the deltoid muscle posterior branch continues as the cutaneous branch, **n. cutaneous brachii lateralis superior**, which innervates the skin of the deltoid and the postero-lateral region of the arm in its upper part.

The long branches:

Among the long branches we can distinguish the anterior branches for the flexors and pronators of upper limb (nn. musculocutaneus, medianus and ulnaris) and the posterior branches for the extensors and supinators of upper limb (n. radialis).

1. The musculocutaneous nerve (n. musculocutaneus) originates from the lateral trunk of the brachial plexus (from C5-C7), pierces m. coracobrachialis and innervates all the anterior muscles of the arm**: mm. coracobrachialis, biceps brachi and brachialis**. On passing between the latter two onto the lateral side of the upper arm, it continues onto the forearm as **the lateral cutaneous nerve of the forearm** (n. cutaneus antebrachii lateralis) passes behind **the cephalic vein**, and divides, opposite the elbow-joint, into **a ventral** and **a dorsal** branches, supplying the skin of the radial (lateral) side of the forarm and the skin of the thenar. The nerve also sends a small branch to the elbow joint and the humerus, which enters the nutrient foramen with the accompanying artery.

2. The median nerve (n. medianus) (C5- Th1), arises from the medial and lateral cords in two roots which embrace the a. axillaris in front. It then passes into the **sulcus bicipitalis medialis** together with the brachial vessels (artery and veins), and ulnar nerve. In the cubital fossa the nerve runs under the **m. pronator teres** (between its heads) and **the superficial flexor of the fingers** and then between the latter and the **m. flexor digitorum profundus** and into **the sulcus medianus** in the middle of the forearm followinf to the palm. On the upper arm, the median nerve gives **off no** branches. First branches will supply elbow joint (rami articulares).. On **the forearm** it gives off rami musculares to all the muscles of the anterior flexor group, with the exception of the **m. flexor carpi ulnaris** and the ulnar (medial) part of **the deep flexor of the fingers** nearest to it.

One of the branches, **the anterior interosseous nerve** (n. interosseus lantebrachid anterior) accompanies the **a. interossea anterior** on the interosseous membrane and innervates the deep flexor muscles (m. flexor pollicis longus and part of the flexor digitorum profundus), m. pronator quadratus and the radiocarpal joint. The median nerve gives off a thin cutaneous branch, **the palmar cutaneous branch** (of the median nerve) (ramus palmaris n. mediani) over the radiocarpal joint. This branch supplies a small area of skin on the thenar and the palm. The median nerve passes onto the palm through **the canalis carpi** together with the tendons of the flexors and divides into **three branches**, **the common plantar digital nerves** (nn. digitales palmares communes) which run along the first, second and third metacarpal spaces under the palmar aponeurosis toward the fingers. The **first branch** innervates the muscles of **the thenar** with <u>the exception</u> of *the m. adductor pollicis and the deep head of the m. flexor pollicis brevis which are innervated by the ulnar nerve.* The common palmar digital nerves, in turn, divide into **seven proper palmar digital nerves** (nn. digitales palmares proprii) which pass to both sides of the thumb, to the index and middle fingers and to the radial side of the ring finger. The same branches also supply the skin on the radial side of the palm; the digital nerves also supply **the first and second vermiform muscles**.

3. The ulnar nerve (n. ulnaris) which emerges from the medial trunk of the brachial plexus (C7-Th1) passes on the medial side of the upper arm to the posterior surface of the medial epicondyle (it lies under the skin here and this is why it gets hurt so often, causing a prickling sensation in the middle zone of the forearm) and then extends in the sulcus ulnaris and further in the canalis carpi ulnaris where it runs, together with the arteries and veins of the same name, to the palm. On the surface of the retinaculum flexorum it transforms into its terminal branch **-** the ramus palmaris n. ulnaris.

Like the median nerve, the ulnar nerve **does not give rise** to any branches on the upper arm. First branches also will supply elbow joint (rami articulares). **Rami musculares** for the **m. flexor carpi ulnaris** and its neighbouring portion of the m. flexor digitorum profundus. **Ramus cutaneus palmaris** to the skin of the **hypothenar**.

Ramus dorsalis n. ulnaris emerges through the space between the m. flexor carpi ulnaris and the ulnar bone to reach the skin of the dorsal surface of the hand where it divides into **five dorsal digital branches**, nn. digitales dorsales, for the little and ring fingers and the ulnar side of the middle finger (lateral half of dorsal side of the skin of the hand).

Ramus palmaris n. ulnaris, the terminal branch of the ulnar nerve, at the level of **the os pisiforme** divides into the **superficial** and **deep** branches, of which the superficial (**ramus superficialis**) supplies, via a small muscle branch, the m. palmaris brevis and then the skin on the ulnar side (hypothenar) of the palm and, on dividing, gives off **three nn. digitales palmares proprii** to both sides of the little finger and to the **ulnar side of the ring finger**. (Skin innervations of the hand palnmar surface: **the median nerve** - 3.5 fingers and **the ulnar nerve** - 1,5 fingers.)

Ramus profundus, the deep branch of the ulnar nerve, together with the deep branch of the a. ulnaris passes through the space between the m. flexor and m. abductor digiti minimi (canal Guyon) and accompanies the deep palmar arch. There it innervates all the muscles of hypothenar, all mm. interossei, the third and fourth mm. lumbricales, and from the muscles of the thenar - m. adductor pollicis and the deep head of the m. flexor pollicis brevis. Ramus profundus ends in a thin anastomosis with n. medianus.

4. The medial cutaneous nerve of the arm (n. cutaneus brachii medialis, *nerve of Wrisberg*) arises from the **medial trunk** of the plexus (from C8, Th1). It descends along the medial side of the brachial artery to the middle of the arm, where it pierces the deep fascia, and is distributed to the skin of the back of the lower third of the arm, extending as far as the elbow, where some filaments are lost in the skin in front of the medial epicondyle, and others over the olecranon. It communicates with a branch of the medial antibrachial cutaneous nerve.

In some cases the medial brachial cutaneous nerve and **n. intercostobrachialis** (perforating branch of the second thoracic nerve) are connected by two or three filaments, which form a plexus in the axilla. In other cases the intercostobrachial is of large size, and takes the place of the medial brachial cutaneous, receiving merely a filament of communication from the brachial plexus, which represents the latter nerve; in a few cases, this filament is wanting.

5. The medial cutaneous nerve of the forearm (n. cutaneus antebrachii medialis) also arises from the **medial trunk** of the plexus (from C8, Th1) and lies in the axilla next to the ulnar nerve; in the upper part of the upper arm it is located medially of the brachial artery next to **v. basilica** together with which it pierces the fascia and becomes subcutaneous. This nerve innervates the skin on the ulnar (medial) side of the forearm down to the wrist.

6. The radial nerve (n. radialis) (C5-C8, Th1), is **the thickest** nerve among the long branches of the brachial plexus, a continuation of **the posterior trunk** of the brachial plexus. It passes posteriorly of the brachial artery together with **the profunda brachii artery** onto the posterior surface of the upper arm, runs around the humerus to be lodged in **the canalis humeromuscularis**, and then, piercing **the lateral intermuscular septum** from back to front, emerges into the space between the m. brachioradialis and m. brachialis. Here the nerve divides into **the superficial** (ramus superficialis) and **deep** (ramus profundus) **branches**. Prior to this, the radial nerve gives rise to the following branches:

Muscular branches (rami musculares) for arm extensors - m. triceps brachi and m. anconeus. The last small branch also supplies the capsule of the elbow joint and the radial - epicondyle of the humerus. This is why pain spreads along the entire length of the radial nerve in inflammation of the epicondyle (epicondylitis).

The posterior cutaneous nerve of the arm and **the lower lateral cutaneous nerve of the arm** (nn. cutanei brachii posterior and lateralis inferior) branch out in the skin of the posterior and inferior parts of the postero-lateral surface of the arm.

The posterior cutaneous nerve of the forearm (n. cutaneus antebrachii posterior) arises from the radial nerve **in the canalis humeromuscularis**, emerges under the skin at the origin of the m. brachioradialis and spreads over the dorsal surface of the skin of the forearm.

Muscular branches (rami musculares) pass to the m. brachioradialis and m. extensor carpi radialis longus.

1. The superficial branch of the radial nerve (ramus superficialis) passes to the forearm into **the sulcus radialis** laterally of the a. radialis, and then in the lower third of the forearm through the space between the radial bone and the tendon of the m. brachioradialis goes over to the dorsal surface of the hand and supplies with **five dorsal branches**, the dorsal digital nerves (nn. digitales dorsales) along the sides of the thumb and index finger, and the radial side of the middle finger. These branches usually end at the level of the distal interphalangeal joints. They anastomose with the ramus dorsalis n. ulnaris. Thus every finger is supplied with two dorsal and two palmar nerves passing along both sides. The dorsal nerves arise from the radial nerve and the ulnar nerve, each innervating two and a half fingers (50/50).

2. The deep branch (ramus profundus) passes through the m. supinator (**supinator canal**) and, having supplied it with a branch, continues onto the dorsal surface of the forearm, innervating the m. extensor carpi radialis brevis and all the posterior muscles of the forearm. The continuation of the deep branch, **n. interosseus (antebrachii) posterior**, descends between the extensors of the thumb to the radiocarpal joint, which it supplies. It can be seen by the route followed by the radial nerve that it supplies all the extensors both of the upper arm and of the forearm and also a radial group of muscles in the forearm. In correspondence with this it also innervates the skin on the extensor surface of the upper arm and forearm. The radial nerve, which is the continuation of the posterior trunk, functions as if it were the posterior nerve of the hand.

The anterior branches of the thoracic nerves

The anterior primary rami (**rami ventrales)** of the thoracic nerves (nn. thoracici), are called **intercostal nerves** (nn. intercostales) because they are located in the intercostal spaces, but the twelfth nerve runs along the lower edge of the twelfth rib (**n. subcostalis**). Each intercostal nerve gives off **a communicating branch to the sympathetic trunk** and is at first covered only by the pleura, but then it passes down from the posterior intercostal artery and enters the space between the external and internal intercostal muscles and then passes along the inferior edge of the rib forward. The upper six intercostal nerves reach the edge of the sternum, the lower six penetrate the thickness of the peritoneal wall where in the space between the transverse and the internal oblique muscles they pass to **the rectus muscle** of the abdomen through its sheath. The twelfth intercostal nerve passing posteriorly obliquely on the m. quadratus lumborum approaches closely with its anterior end **the pubic symphysis** and ends in the lower part of **the rectus muscle and m. pyramidalis**. On their way the intercostal nerves give off **muscular branches** to all the ventral muscles in the walls of the thoracic and peritoneal cavities, and to the muscles of ventral origin on the back: **mm. serrati posteriores superiores and inferiores and mm. levatores costarum**. They also participate in innervation of the pleura and peritoneum **(nn. pleurales and peritoneales).**

Two rows of **piercing branches** arise from the intercostal nerves. They supply the skin on the lateral surface of the thorax and abdomen, **lateral cutaneous branches** (rami cutanei laterales) (pectorales and abdominales) on the anterior surface where divide into anterior and posterior branches, and **anterior cutaneous branches** (rami cutanei anteriores) (pectorales and abdominales). Branches originate from them to the mammary gland are: from the lateral surface **- rami mammarii laterales**, and from the anterior surface **-** rami **mammarii mediales**.

The anterior cutaneous branches are continuations of the six intercostal nerves; they pierce the rectus abdominis muscle and the anterior layer of its sheath and are distributed in the skin of the abdomen in this area.

The lumbosacral plexus

The lumbosacral plexus (plexus lumbosacrococcigealalis) is composed of the anterior branches of the **lumbar**, **sacral** and **coccygeal nerves**. This common plexus is divided into separate parts, or separate plexuses: **lumbar**, **sacral** and **coccygeal**.

The lumbar plexus

The lumbar plexus (plexus lumbalis) is formed of the anterior branches of **three superior lumbar nerves** and the upper part of **the fourth superior lumbar nerve,** and of a small branch from the twelfth intercostal nerve. The plexus lies in front of the transverse processes of the lumbar vertebrae in the thickness of the m. psoas major and gives rise to a number of branches which emerge partly from under the lateral, partly from under the medial edge of this muscle, while another part of them pierces it and appears on its frontal surface.

The mode in which the plexus is arranged varies in different subjects. It differs from the brachial plexus in not forming an intricate interlacement, but the several nerves of distribution arise from one or more of the spinal nerves, in the following manner: the first lumbar nerve, frequently supplemented by a twig from the last thoracic, splits into an upper and lower branch; the upper and larger branch divides into the iliohypogastric and ilioinguinal nerves; the lower and smaller branch unites with a branch of the second lumbar to form the genitofemoral nerve. The remainder of the second nerve, and the third and fourth nerves, divide into ventral and dorsal divisions. The ventral division of the second unites with the ventral divisions of the third and fourth nerves to form the obturator nerve. The dorsal divisions of the second and third nerves divide into two branches, a smaller branch from each uniting to form the lateral femoral cutaneous nerve, and a larger branch from each joining with the dorsal division of the fourth nerve to form the femoral nerve. The accessory obturator, when it exists, is formed by the union of two small branches given off from the third and fourth nerves.

The **branches** of the lumbar plexus may therefore be arranged as follows:

Iliohypogastric, Ilioinguinal, Genitofemoral, **Dorsal divisions**: Lateral femoral cutaneous, Femoral, **Ventral divisions**: Obturator, Accessory obturator

1. Rami musculares to the m. psoas major and minor, m. quadratus lumborum and mm. intertransversarii laterales lumborum.

2. The iliohypogastric nerve (n. iliohypogastricus) (L1) arises from the first lumbar nerve and.emerges from under the lateral edge of the m. psoas major and stretches on the anterior surface of the m. quadratus lumborum parallel to the twelfth intercostal nerve. The iliohypogastric nerve is a segmentary nerve and like the latter it passes between the transverse and internal oblique muscles of the abdomen, supplying them with **muscular branches**, and also turn along of edge of iliac crest and innervates the skin of the upper part of the buttocks (**ramus cutameus lateralis**) and the inguinal canal above the level of its superficial orifice, hypogastric region of abdominal anterior wall (**ramus cutameus anterior**).

3. The ilioinguinal nerve (n. ilio-inguinalis) (L1) is also a segmentary nerve, it emerges from under the lateral edge of the m. psoas major and runs parallel to and downward of the iliohypogastric nerve. It perforates the m. transversus abdominis, near the anterior part of the iliac crest, and communicates with the iliohypogastric nerve between the m. transversus and the m. obliquus internus. The nerve then pierces the m. oliquus internus, distributing filaments to it, and, accompanying the spermatic cord through the subcutaneous inguinal ring, is distributed to the skin of the upper and medial part of the thigh, to the skin over the root of the penis and upper part of the scrotum in the male, and to the skin covering the mons pubis and labium majus in the female. The size of this nerve is in inverse proportion to that of the iliohypogastric. Occasionally it is very small, and ends by joining the iliohypogastric; in such cases, a branch from the iliohypogastric takes the place of the ilioinguinal, or the latter nerve may be altogether absent. and then directly in the inguinal canal, exits through the superficial inguinal ring and branches out in the skin of the pubis and scrotum or the labia majora.

4. The genitofemoral nerve (n. genitofemoralis) (L2) arises from the first and second lumbar nerves. It runs through the thickness of the m. psoas major onto its anterior surface and divides into **two branches**, one of which, **the femoral branch** (r. femoralis), descends forward to inguinal (Poupart's) ligament, passes under it, and branches in the skin of the thigh immediately below this ligament.

The other, **the genital branch** (r. genitalis), pierces the posterior wall of the inguinal canal and joins the spermatic cord (behind), supplying the m. cremaster and the coats of the testicle. In the female, it accompanies the round ligament of the uterus, and is lost upon it.

5. The lateral cutaneous nerve of the thigh (n. cutaneus femoris laterails) (L2, L3), originates from under the lateral edge of the m. psoas major and passes over the surface of the m. iliacus from top to buttock and then laterally to the spina iliaca anterior superior, where it pierces the abdominal wall and emerges onto the thigh, becomes subcutaneous and descends along the lateral surface of the thigh to the knee, innervating the skin.

The skin of the external surface of the thigh is also innervated by the iliohypogastric and subcostal nerves.

6. The femoral nerve (n. femoralis) is **the largest branch** of the lumbar plexus (L2, L3, L4). It descends through the fibers of the m. psoas major, emerging from the muscle at the lower part of its **lateral border**, and passes down between it and the Iliacus. It emerges through **the lacuna musculorum** together with iliopsoas muscle, onto the anterior side of the thigh. It lies laterally of the femoral artery, separating from it with a deep fascia of the fascia lata, and then ramifies into numerous branches. Some of these branches, **rami musculares**, innervate the m. quadriceps, m. sartorius and m. pectineus, while others, **the rami cutanei anteriores**, supply the skin of the antero-medial surface of the thigh. One of the cutaneous branches of the femoral nerve, the longest branch, **the saphenous nerve**, stretches in **canalis adductorius** laterally of the femoral artery. At **the hiatus adductorius anterior** the nerve leaves the artery, pierces the anterior wall of the canal and becomes superficial. On the leg the nerve is accompanied by **the v. saphena magna.** It gives rise to **the infrapatellar branch** (ramus infrapatellaris) in the skin of the lower part of the leg and to the medial cutaneous nerve of the leg (rami cutanei cruris mediates) in the skin of the medial surface of the leg down to the medial edge of the foot until big toe, communicating with the medial branch of the superficial peroneal nerve..

In addition to the principal femoral nerve there is a supplementary femoral nerve.

7. The obturator nerve (n. obturatorius) (L2-L4). It descends through the fibers of the m. psoas major, and emerges from its **medial border**; it then passes behind the common iliac vessels, and on the lateral side of the hypogastric vessels and ureter, which separate it from the ureter, and runs along the lateral wall of the lesser pelvis, above and in front of the obturator vessels, to the upper part of the obturator foramen. Here it enters the thigh through **the obturator cana**l, and divides into **the anterior** and **posterior branches**.

The posterior branch (ramus posterior) innervates the m. obturatorius externus, m. adductor magnus and the hip joint. It usually gives off an articular filament to the knee-joint.

The anterior branch (ramus anterior) supplies the other adductor muscles together with the m. gracilis and m. pectineus, and, besides, it gives rise to a long **cutaneous branch** (ramus cutaneus) which passes down between the adductor muscles the cutaneous branch runs under the skin on the medial side of the thigh in its lower half, which it innervates. At the lower border of the adductor longus muscle it communicates with the anterior cutaneous and saphenous branches of **the femoral nerve**, forming a kind of plexus (**subsartorial plexus**).

8. The accessory obturator nerve (n. obturatorius accessorius) is present in about 30 % of cases. It is of small size, and arises from the ventral divisions of the third and fourth lumbar nerves. It descends along the medial border of the m. psoas major, crosses the superior ramus of the pubis, and passes under the m. pectineus, where it divides into numerous branches. One of these supplies **the m. pectineus,** penetrating its deep surface; another is distributed **to the hip-joint**; while a third communicates with the anterior branch of the obturator nerve. Occasionally the accessory obturator nerve is very small and is lost in the capsule of the hip-joint. When it is absent, the hip joint receives two branches from the obturator nerve.

The sacral plexus

The sacral plexus (plexus sacralis), (S1-S3). The sacral plexus is formed by **the lumbosacral trunk**, the anterior division of the first, and portions of the anterior divisions of the second and third sacral nerves.

The lumbosacral trunk comprises the whole of the anterior division of the **fifth and a part of that of the fourth lumbar nerve**; it appears at the medial margin of the m. psoas major and runs downward over the pelvic brim to join the first sacral nerve. The anterior division of the third sacral nerve divides into an upper and a lower branch, the former entering the sacral and the latter the pudendal plexus.

The nerves forming the sacral plexus converge toward the lower part of **the greater sciatic foramen** (through **the foramen infrapiriforme**), and unite to form a flattened band, from the anterior and posterior surfaces of which several branches arise. The band itself is continued as the **sciatic nerve.** which splits on the back of the thigh into the **tibial** and **common peroneal nerves;** these two nerves sometimes arise separately from the plexus, and in all cases their independence can be shown by dissection.

The branches originating from the sacral plexus may be divided into **short** and **long ones**. The short ones branch out in the region of the pelvic girdle and the **long branches** supply the whole lower extremity except for that part which is supplied by branches of the lumbar plexus.

The short branches:

1. **The muscular branches** (rami musculares): **the nerve for piriform muscle -** for the m. piriformis (from S1 and S2), the **nerve to the obturator internus and gemellus superior -** m. obturatorius internus, the **nerve to the quadratus femoris and gemellus inferior -** mm. gemelli and quadratus femoris (from L4, L5, S1 and S2), for mm. levator ani and coccygeus (S3-S4).

2. **The superior gluteal nerve** (n. gluteus superior) (L4 and L5 and from S1) emerges through **the foramen suprapiriforme** from the pelvis together with the artery of the same name and divides into **a superior** and **an inferior branch**. The **superior branch** accompanies the upper branch of the deep division of the superior gluteal artery and ends in the m., gluteus minimus. The **inferior branch** runs with the lower branch of

the deep division of the superior gluteal artery across the m. gluteus minimus; it gives filaments to the mm. glutei medius and minimus, and ends in the m. tensor fasciae latae.

3. The inferior gluteal nerve (n. gluteus inferior) (L5, S1, S2) emerges through **the foramen infrapiriforme** lateral of the artery of the same name; its branches supply **the m. gluteus maximus** and the capsule of the hip joint.

4. The pudendal nerve (n. pudendus) emerges through together with the a. pudenda interna and, curving around the spina ischiadica, passes back into the pelvis through **the foramen ischiadicum minus**. Further the pudendal nerve together with the same artery passes along the lateral wall of **the fossa ischiorectalis**. Within the limits of the latter it gives off **the inferior haemorrhoidal nerves** (nn. rectales inferiores) which supply **the external sphincter** (m. sphincter ani externus) and the skin of the region around the anus. At the level of the tuber ischiadicum at the posterior edge of the diaphragma urogenitale the pudendal nerve divides into **the perineal nerves** and **dorsal nerve of the penis** (nn. perinei and n. dorsalis penis) (**clitoridis**). The first run forward and innervate the m. ischiocavernosus, m. bulbospongiosus and m. transversus perinei superficialis and the skin of the perineum. The terminal branches supply the skin of the posterior side of the scrotum, **the scrotal branches** (nn. scrotales posteriores), and the labia majora, **the labial branches** (nn. labiales posteriores). **The dorsal nerve of the penis** (**clitoridis**) attends a. dorsalis penis in the thickness of the diaphragma urogenitale, gives off small branches to the m. transversus perinei profundus and m. sphincter uretrae, and passes onto the dorsum penis (or clitoris) where it is distributed in the skin mainly of the glans penis. A large number of vegetative fibres pass in the composition of the pudendal nerve.

The long branches

1. The posterior cutaneous nerve of the thigh (n. cutaneus femoris posterior) (S1, S2, S3) emerges from the pelvis together with the sciatic nerve and then descends under the m. gluteus maximus onto the posterior surface of the thigh. From its medial side it gives off small gluteal branches which run under the skin of the lower part of the buttock (**nn. clunium inferiores**) and to the perineum—perineal branches (**rami perineales**). On the surface of the posterior thigh muscles it reaches down to the popliteal fossa and gives rise to numerous branches which are distributed in the skin of the posterior surface of the thigh and the calf region.

2. The sciatic nerve (n. ischiadicus) is the largest nerve in the entire body and is actually the direct continuation of the sacral plexus that contains fibers of all its roots. It emerges from the pelvic cavity through the large ischiadic foramen below the m. piriformis **the foramen infrapiriforme** and is covered by the m. gluteus maximus, placed in the middle of greater trohanter and ischadic tuberosity. Further down the nerve emerges from under the lower edge of this muscle and descends perpendicularly on the posterior surface of the thigh under the flexors of the leg. In the upper part of the popliteal fossa it usually divides into its two main branches: the medial thicker one **- the tibial** (medial poplitea)l nerve (n. tibialis) and the lateral, thinner one **- the common fibular** (lateral poplitea)l nerve (n. peroneus [fibularisl communis). Quite often the nerve is already divided into two separate trunks the entire length of the posterior part of the thigh.

Branches of the sciatic nerve:

1. Muscular branches (rami musculares) to the posterior muscles of the thigh: m. semitendinosus, m. semimembranosus and to the long head the m. biceps femoris and also to the posterior part of the m. adductor magnus. The short head of the m. biceps receives a small branch from the common peroneal nerve. A small branch also arises from the common peroneal nerve to the knee joint.

2. The tibial nerve (n. tibialis) (L4 L5 S2 S3) descends directly through the middle of the popliteal fossa along the tract of the popliteal vessels, then enters **the canalis cruropopliteus**, accompanying the a. and vv. tibiales posteriores in this canal, until it reaches the medial malleolus. Behind the latter the medial popliteal nerve divides into its terminal branches **- the lateral and medial plantar nerves** (nn. plantares lateralis and medialis) in the plantar sulci of the same name (sulcus plantaris madialis et sulcus plantaris lateralis).

In the popliteal fossa **the rami musculares** branch out from the medial popliteal nerve to the m. gastrocnemius, m. plantaris, m. soleus and m. popliteus. Several small branches pass to **the knee joint**. Moreover, in the popliteal fossa the tibial nerve gives rise to a long cutaneous branch **the lateral cutaneous nerve of calf of the leg** (n. cutaneus surae medialis), which runs down together with **the vena saphena parva (**being located in **the Progoff canal** – the fascial crural space at the level of gastrocnemian heads**)** and innervates the skin of the posteromedial surface of the leg. On the leg the tibial nerve supplies all three deep muscles with small branches: m. tibialis posterior, m. flexor hallucis longus and m. flexor digitorum longus and the posterior side of the talocrural joint and behind the medial malleolus it gives rise to cutaneous branches, **rami calcanei mediales**, which pass to the skin of the heel and the medial edge of the foot.

The medial plantar nerve (n. plantaris medialis) together with the artery of the same name passes in **the sulcus plantaris medialis** along the medial edge of the m. flexor digitorum brevis and supplies this muscle and the muscles of the medial group, with the exception of the m. adductor hallucis and the lateral head of the m. flexor hallucis brevis. The nerve finally ramifies into **seven nerves - proper plantar digital nerves** (nn. digitales plantares proprii) of which one passes to the medial edge of the big toe and also supplies **the first and second mm. lumbricales** while the remaining six nerves innervate the skin of the sides of toes facing each other, beginning with the lateral side of the big toe and ending with the medial side of the fourth toe.

The lateral plantar nerve (n. plantaris lateralis) runs in the same direction as the artery of the same name in **the sulcus plantaris lateralis**. It supplies by means of rami musculares all three muscles of the lateral group of the sole and the m. quadratus plantae and divides into two branches, **a deep** and **a superficial** one. **The deep branch** (ramus profundus) runs together with the plantar arterial arch and supplies **the third and fourth mm. lumbricales** and all the dorsal interossei muscles, and also the m. adductor hallucis and the lateral head of the m. flexor hallucis brevis. **The superficial branch** (ramus superficialis) gives off branches to the skin of the sole and divides into three **proper plantar digital nerves** (nn. digitales plantares proprii) running to both sides of the fifth toe and to the side of the fourth toe facing the fifth. The distribution of the medial and lateral plantar nerves corresponds to the direction taken by the ulnar and median nerves of the hand.

3. The common fibular nerve (n. peroneus [fibularis] communis) (L4, L5, S1, S2), runs laterally of the n. tibialis to the head of the fibula where it pierces the beginning of the peroneus longus muscle and divides into **the superficial** and **deep branches**. On its way the common fibular nerve gives rise to **the lateral cutaneous nerve of the leg** (n. cutaneus surae laterally) which innervates the skin of the lateral surface of the leg. Below the middle of the leg the lateral cutaneous nerve joins **the medial cutaneous nerve** to form **the sural nerve** (n. suralis) which curves around the lateral malleolus from the back giving rise to branches to the skin of the heel (**rami calcanei laterales**), and then continues under the name of **the dorsal lateral cutaneous nerve of the foot** (n. cutaneus [pedis] dorsalis lateralis) along the lateral edge of the dorsal surface of the foot, also supplying the skin of this region on the lateral side of the small toe.

***The superficial fibular nerve** (n. peroneus [fibularis] superficialis), descends between the mm. peronei (long and short) into **the canalis musculofibularis superior**, giving them muscle branches. On the border between the middle and lower third of the leg it pierces the fascia functioning only as a cutaneous nerve and descends to the middle of the dorsal surface of the foot to divide into **two branches**. One of them **the medial dorsal cutaneius nerve of the foot** (n. cutaneus [pedis] dorsalis medialis) supplies the medial surface of the big toe and the edges of the second and third toes facing each other (**nervi digitales dorsales**). The other, **the intermediate dorsal cutaneius nerve of the foot** (n. cutaneus [pedis] dorsalis intermedius) divides into the **nn. digitales dorsales pedis** supplying the approximate surfaces of the second to fifth toes.

***The deep fibular nerve** (n. peroneus [fibularis] profundus), passes in attendance to the a. tibialis anterior, giving branches to the m. tibialis anterior, in. extensor digitorum longus and m. extensor hallucis longus and the ramus articularis to the talocrural joint. The anterior tibial nerve together with the artery attending it emerges onto the dorsal surface of the foot, innervates the short extensor of the toes and then, dividing into **two digital branches** (nn. digitales dorsales) supplies the skin of the surfaces of the **big and second toes facing each other.**

Part of the sacral plexus which belongs to the vegetative nervous system is made up of preganglionary parasymphathetic fibres which begin in the lateral horns of the **second to fourth segments of the spinal cord**. These fibres as pelvic **splanchnic nerves** (nervi splanchnici pelvini) pass to the nerve plexuses of the pelvis that innervate the internal organs of the pelvis: the urinary bladder, the sigmoid colon, the rectum and the internal genital organs.

The coccygeal plexus

The coccygeal plexus (plexus coccygeus) is composed of the anterior branches of the fifth sacral and the coccygeal nerves. It gives rise to the thin **anococcygeal nerves** (nn. anococcygei) which join with the posterior branch of the coccygeal nerve, pierce the sacrotuberous ligament and branches out in the skin at the top of the coccyx.

The cranial nerves

There are twelve pairs of cranial nerves:

I - n. olfactorius;
II - n. opticus;
III - n. oculomotorius;
IV - n. trochlearis;
V - n. trigeminus;
VI - n. abducens;
VII - n. facialis;
VIII - n. vestibulocochlearis;
IX - n. glossopharyngeus;
X - n. vagus;
XI - n. accessorius;
XII - n. hypoglossus.

The cranial nerves **(nn. craniales or nn. cerebrales [BNA] or nn. encephalici)** have some features that distinguish them from the spinal nerves. These features mainly depen d on the different conditions under which the brain and the head developed as compared with the spinal cord and trunk. The first two cranial nerves connected with the prosencephalon in their character and origin occupy quite a different place among all the nerves. They are outgrowths of the brain. Although the other cranial nerves are not different in principle from the spinal nerves, they are nonetheless characterized by the fact that not a single one of them fully corresponds to the cerebrospinal, nerve that is composed of an anterior and a posterior root. Each of the cranial nerves is either one of these two roots which in the region of the head are never joined together; this resembles similar relations existing among spinal nerves of primitive vertebrates.

The third, fourth, sixth and twelfth cranial nerves correspond to the anterior roots of the spinal nerves, while the fifth, seventh, eighth, ninth and tenth nerves are homologous with the posterior roots.

The cranial nerves, like the spinal nerves, have nuclei of grey matter: the somatic-sensory (corresponding to the posterior horns of the grey matter of the spinal cord), the somatic-motor (corresponding to the anterior horns) and vegetative. These last may be divided into visceral-sensory and visceral-motor (corresponding to the lateral horns) of which the visceral-motor nerves innervate not only the smooth muscles, but the striated muscles of visceral origin. Taking into consideration that the visceral striated muscles have acquired the features of somatic muscles, all the nuclei of the cranial nerves bearing relation to striated muscles, irrespective of their origin, should best be designated as somatic-motor nerves.

As a result, the composition of the cranial nerves includes the same components as there are in the spinal nerves.

Afferent components.

1. Somatic-sensory fibres emerging from the organs appreciating physical stimuli (pressure, temperature, sound and light), i.e. from the skin, the organs of hearing and vision; second, fifth, eighth cranial nerves.

2. Visceral-sensory fibres arising from the organs which appreciate chemical stimuli (by particles of various substances dissolved or suspended in a external environment, or in internal cavities), i.e. from the nerve endings in the digestive organs and other internal organs, from special organs of the pharynx, the oral (organs of taste) and nasal (olfactory organs) cavities; the first, fifth, seventh, ninth, tenth cranial nerves.

Efferent components.

1. Somatic-motor fibres innervating the striated muscles, namely: the parietal muscles originating from the cephalic myotomes, the ocular muscles (third, fourth, sixth cranial nerves), and the sublingual muscles (twelfth cranial nerve), and also the muscles which became part of the first portion of the digestive tract later; these muscles of the skeletal (somatic) type belonged to the visceral (branchial) apparatus and in mammals and man became the muscles of mastication and facial expression, etc. (fifth, seventh, ninth, tenth, eleventh cranial nerves).

2. Visceral-motor fibres innervating the visceral muscles, i.e. the smooth muscles of the vessels and internal organs (organs of digestion and respiration), the heart muscle and various kind of gland (secretory fibres); seventh, ninth, tenth cranial nerves.

3. Sympathetic fibres from corresponding sympathetic ganglia are included as components of the motor nerves to the same organs.

Out of the twelve pairs of cranial nerves the somatic-sensory is the eighth nerve, the somatic-motor are the third, fourth, sixth, eleventh and twelfth nerves. The remainder (fifth, seventh, ninth, tenth) are mixed nerves.

The olfactory nerve, which may be called visceral-sensory, and the visual nerve, somatic-sensory, occupies a special place as it was mentioned above.

The small number of somatic-motor nerves as compared with the rest is connected with the reduction of cephalic myotomes which give rise only to ocular muscles. The development of mixed nerves containing visceral components is connected with the evolution of the anterior part of the alimentary tube (grasping and respiratory) in the region of which the visceral apparatus develops with a complex sensory area and considerable musculature.

The olfactory (1st) nerves

The olfactory nerves (nn. olfactorii) develop from the olfactory brain which originated in association with the olfactory receptor. They contain visceral-sensory fibres which run from the organs of reception of chemical stimuli. Since the nerves are outgrowths of the prosencephalon, they have no ganglion; they are an accumulation of thin nerve filaments, **fila olfactoria**, about fifteen to twenty in number, which are the central processes of olfactory cells located in the olfactory region of the mucous membrane of the nose. Fila olfactoria pass through the openings of **the lamina cribrosa** in the superior wall of the nasal cavity and terminate in **the olfactory bulb**, which continues in **the olfactory tract** and **the olfactory triangle.** In the olfactory triangle tract divide in tree tracts: stria olfactoria lateralis, media et medialis. The cortical analyzer is the gyrus fornicatus. Lateral tract runs to uncus and partlly to corpus amygdaloideum. Middle tract finish in the substantia perforata anterior of the same side and in the opposite side (by commissura alba anterior). Axons of neurones from the substantia perforata anterior follow to fornix through lamina pellucida and finally reach the uncus by fimbria hippocampi. The medial tract goes to aria subcalosa, septum pillucidum and after this to the fornix. Another part of this last tract follows by stria logitudinalis medialis, after by gyrus fasciolatus and gyrus dentatus to uncus.

The optic (2nd) nerve

The optic nerve (n. opticus) in the process of embryogenesis grows as a peduncle of the optic cup from the diencephalon. In the process of phylogenesis the optic nerve is connected with the mesencephalon which originates in association with the receptor of light. This explains its strong ties with these portions of the brain. It is a conductor of light stimuli and contains somatic-sensory fibres. As a derivative of the brain it has no ganglion like the first pair of cranial nerves, while the afferent fibres which are part of it are a continuation of the axons of multipolar (ganglionar) nerve cells of the retina. On leaving the posterior periphery of the eyeball **(pars bulbaris)** the optic nerve runs from the orbit (**pars orbitalis**) through **the optic canal (pars canalicularis)**, and, on entering **the cranial cavity (pars cranialis)** together with a similar nerve from the opposite side, forms **the optic chiasma** located in the optic groove (sulcus chiasmatis) of the sphenoid bone (the chiasma is **partial** because only the medial fibres of the nerve cross).

The optic tract (tractus opticus) is a continuation of the visual pathway after the chiasma. It terminates in **the lateral geniculate body** (corpus geniculatum laterale), **pulvinar thalami** and in t**he nuclei colliculi superioris tecti** of lamina quadrigemina. The cortical center is located in **occipital lobe**. Visual information from subcortical centers reach the primary visual center (in both sides of t**he calcarinus groove**) by white matter fibres **the radiatio optica** (Gratiole).

The oculomotor (3rd) nerve

The oculomotor nerve (n. oculomotorius), developmentally the motor root of the first preauricular myotome, is a muscle nerve. It contains: (1) **efferent** (motor) fibres arising from its motor nucleus (located at the level of superior colliculi tecti) and running to most of the extrinsic muscles of the eyeball and (2) **parasympathetic** fibres running from **the accessory oculomotor nucleus** (Edinger Westphal) to the intrinsic ocular muscles (m. sphincter pupillae and m. ciliaris).

The oculomotor nerve emerges from the brain along the medial edge of the peduncle of the brain and passes to **the fissura orbitalis superior** through which it enters the orbit. Here it divides into two branches.

1. The superior branch (ramus superior) that supplies **the superior rectus** and **the levator palpebrae superius muscles.**

2. The inferior branch (ramus inferior) supplies **the inferior rectus, medial rectus and inferior oblique muscles.** The inferior branch gives rise to a nerve root that passes to **the ciliary ganglion (**ganglion ciliare**).** The motor root of the ciliary ganglion (**radix oculomotoria**) carries parasympathetic fibres for the sphincter of the pupil and to the ciliary muscle. Since the oculomotor nerve is located at the base of the brain in the interpeduncular cistern, it is abundantly washed over by cerebrospinal fluid. This is why, in inflammation of the meninges (meningitis), this nerve is the first to be affected, particularly its external fibres that innervate the levator palpebrae superius muscle (m. levator palpebrae superior).

The trochlear (4th) nerve

The trochlear nerve (n. trochlearis) is developmentally the motor root of the second preauricular myotome. It is a muscle nerve containing somatic-motor nuclei (located at the level of inferior colliculi tecti) from which arise efferent (motor) fibres to the superior oblique muscle of the orbit. Emerging from **the dorsal side** of the superior medullary velum, it curves laterally around the peduncle of the brain, enters the orbit through **the superior orbital fissure** and supplies **the superior oblique muscle.**

The abducent (6th) nerve

The abducent nerve (n. abducens), the motor root of the third preauricular myotome, is a muscle nerve with a somatic-motor nucleus lodged in the pons (colliculus facialis). The nerve contains efferent (motor) fibres running to t**he lateral (external) rectus muscle** of the eye. Emerging from the brain at the posterior edge of the pons it enters the orbit through **the superior orbital fissure** and supplies **the lateral rectus muscle.**

Afferent (proprioceptive) fibres for the external ocular muscles corresponding to the efferent fibres of the third, fourth and sixth nerves pass together with the first branch of the fifth nerve (n. ophthalmicus).

Many authors allow for the presence of afferent (proprioceptive) fibres in all three motor nerves of the eyeball.

The trigeminal (5th) nerve

The trigeminal nerve (n. trigeminus) develops in association with **the first visceral arch** (mandibular) and is mixed. Its **sensory fibres** supply the skin of the face and the anterior part of the head, bordering posteriorly with the skin area where the posterior branches of the cervical nerves and the branches of the cervical plexus are distributed. The trigeminal nerve is, also a conductor of sensitivity from the receptors of the mucous membranes of the mouth, nose, ear and conjunctiva of the eye, except those parts of these organs which act as specific receptors of the senses (innervated by the first, second, seventh, eighth and ninth pairs).

As a nerve of the first visceral arch, the trigeminal nerve innervates **the muscles of mastication** developing from it and the **muscles of the floor of the mouth**; it also contains the afferent (proprioceptive) fibres arising from the receptors of these muscles; the afferent fibres end in the mesencephalic nucleus (nucleus tractus mesencephalici n. trigemini).

Moreover, the branches of the nerve contain secretory (vegetative) fibres to the glands located in the cavities of the face.

Since the trigeminal nerve is a mixed nerve, it has four nuclei (three sensory and one motor) of which two sensory and one motor nuclei are in the pons and medulla oblongata, while the sensory (proprioceptive nucleus) is in the mesencephalon. The processes of cells contained in the motor nucleus (nucleus motorius) emerge from the pons on the line separating the pons from the middle cerebellar peduncle and connecting the place of emergence of the trigeminal and facial nerves (**linea trigemino-facialis**), forming **the motor root** of the nerve, radix motoria. Next to it **the sensory root**, radix sensoria, enters the brain matter. Both roots comprise **the trunk of the trigeminal nerve** which on emergence from the brain penetrates under the dura mater of the middle cranial fossa and is distributed onto the superior surface of the pyramid of the temporal bone at its apex where **the trigeminal impression** (impressio trigemini) is located. Here the dura mater splits to form a small cavity for it, **cavum trigeminale** (Mekel). In this cavity the sensory root has a large **semilunar** (or Gasser's) ganglion, ganglion trigeminale (semilunare, Gasseri). The central processes of the cells of this ganglion comprise **the sensory root** and run to **the sensory nuclei**: the main sensory nucleus (**nucleus sensorius principalis**

(pontinus) n. trigemini), the **spinal nucleus** (nucleus tractus spinalis n. trigemini) and **the mesencephalic nucleus** (nucleus tractus mesencephalicis n. trigemini), while the peripheral processes are part of the three main branches (divisions) of the trigeminal nerve emerging from the convex edge of the ganglion.

These branches are as follows: **the first**, or **ophthalmic nerve** (n. ophthalmicus) (V1), **the second, maxillary nerve** (n. maxillaris) (V2), and **the third, mandibular nerve** (n. mandibularis) (V3).

The motor root of the trigeminal nerve takes no part in forming the ganglion. It runs freely under the latter and then joins the third division.

Each of the three branches of the trigeminal nerve sends a thin branch to **the dura mater (rr. meningei)**.

In the region of the ramification of each of the three branches of the trigeminal nerve there are several small nerve ganglia which belong to the vegetative nervous system but which are usually described relative to the trigeminal nerve. These vegetative (parasympathetic) ganglia developed from cells which settled during embryogenesis along the course of the trigeminal nerve branches; this explains their lifetime connection, namely,

with n. ophthalmicus through **ganglion ciliare**,

with n. maxillaris through **ganglion pterygopalatinum**,

with n. mandibularis through **ganglion oticum**, and with n. lingualis (from the third branch) through **ganglion submandibulare**.

V1. The ophthalmic nerve

The ophthalmic nerve (n. ophthalmicus) passes out of the cranial cavity into the orbit through **the fissura orbitalis superior**, but prior to its entrance it divides again **into three branches**: n. frontalis, n. lacrimalis and n. nasociliaris.

1. The frontal nerve (n. frontalis) is the largest branch of the ophthalmic nerve, and may be regarded, both from its size and direction, as the continuation of the nerve. It enters the orbit through **the superior orbital fissure**, and runs forward between the m. levator palpebrae superioris and the periosteum. Midway between the apex and base of the orbit it divides into two branches, **supratrochlear** and **supraorbital nerves.**

The **supratrochlear nerve** (*n. supratrochlearis*), the smaller of the two, passes above the pulley of the m. obliquus superior, and gives off a descending filament, to join **the infratrochlear branch** of the nasociliary nerve. It then escapes from the orbit between the pulley of the m. obliquus superior and the supraorbital foramen, curves up on to the forehead close to the bone, ascends beneath the m. corrugators supercili and m. frontalis, and dividing into branches which pierce these muscles, it supplies the skin of the lower part of the forehead close to the middle line and sends filaments to the conjunctiva and skin of the upper eyelid.

The **supraorbital nerve** (*n. supraorbitalis*) passes through the supraorbital foramen (or incisura), and gives off, in this situation, palpebral filaments to the upper eyelid. It then ascends upon the forehead, and ends in two branches, **a medial and a lateral branches**, which supply the skin of the scalp, reaching nearly as far back as the lambdoidal suture; they are at first situated beneath the m. frontalis, **the medial branch** perforating the muscle, **the lateral branch** the galea aponeurotica. Both branches supply small twigs to the pericranium.

2. The lacrimal nerve (n. lacrimalis) is the smallest of the three branches of the ophthalmic. It passes forward in a separate tube of dura mater, and enters the orbit through the narrowest part of **the superior orbital fissure**. In the orbit it runs along the upper border of the m.rectus lateralis, with the lacrimal artery, and communicates with the zygomatic nerve of the maxillary nerve. Through this "anastomosis" the lacrimal nerve receives secretory fibres for the lacrimal gland and also supplies it with sensory fibres. It enters the lacrimal gland and gives off several filaments, which supply the gland and the conjunctiva. Finally it pierces the orbital septum, and ends in the skin of the upper eyelid, joining with filaments of the facial nerve. The lacrimal nerve is occasionally absent, and its place is then taken by the zygomaticotemporal branch of the maxillary. Sometimes the latter branch is absent, and a continuation of the lacrimal is substituted for it.

3. The nasociliary nerve (n. nasociliaris) is intermediate in size between the frontal and lacrimal nerves, and is more deeply placed. It enters the orbit between the two heads of the m. rectus lateralis, and between the superior and inferior rami of the oculomotor nerve. It passes across the optic nerve and runs obliquely beneath the mm. rectus superior and obliquus superior, to the medial wall of the orbital cavity. Here it passes through **the anterior ethmoidal foramen**, and, entering the cavity of the cranium, traverses a shallow groove on the lateral margin of the front part of the cribriform plate of the ethmoid bone, and runs down, through a slit at the side of the crista galli, into the nasal cavity. It supplies by **internal nasal branches ()** to the mucous membrane of the front part of the septum and lateral wall of the nasal cavity. Finally, it emerges, as the **external nasal branch,** between the lower border of the nasal bone and the lateral nasal cartilage, and, passing down beneath the nasal muscle, supplies the skin of the ala and apex of the nose.

The nasociliary nerve gives off the following branches: the **long root of the ciliary ganglion,** the **long ciliary,** and the **ethmoidal nerves.**

The **long root of the ciliary ganglion** (*radix longa ganglii ciliaris*) usually *arises* from the nasociliary between the two heads of the m. rectus lateralis. It passes forward on the lateral side of the optic nerve, and enters the postero-superior angle of the ciliary ganglion; it is sometimes joined by a filament from the cavernous plexus of the sympathetic, or from the superior ramus of the trochlear nerve.

The **long ciliary nerves** (*nn. ciliares longi*), two or three in number, are given off from the nasociliary, as it crosses the optic nerve. They accompany the **short ciliary nerves** from the ciliary ganglion, pierce the posterior part of the sclera, and running forward between it and the choroid, and are distributed to the iris and cornea. The long ciliary nerves are supposed to contain sympathetic fibers from the superior cervical ganglion to **the m. dilator pupillae muscle**.

The **infratrochlear nerve** (*n. infratrochlearis*) is given off from the nasociliary just before it enters the anterior ethmoidal foramen. It runs forward along the upper border of the m. mectus medialis, and is joined, near the pulley of the m. obliquus superior, by a filament from the supratrochlear nerve. It then passes to the medial angle of the eye, and supplies the skin of the eyelids and side of the nose, the conjunctiva, lacrimal sac and caruncula lacrimalis.

The **ethmoidal nerves** (*nn. ethmoidales*) supply the ethmoidal cells; **the posterior ethmoidal nerve** leaves the orbital cavity through the posterior ethmoidal foramen and gives some filaments to the sphenoidal sinus.

The ophthalmic nerve is responsible for the sensory (proprioceptive) innervation of the ocular muscles by means of communications with the third, fourth and sixth nerves.

The ciliary ganglion (ganglion ciliare) has the shape of an oblong swelling about 1.5 mm long; it lies in the posterior part of the orbit on the lateral side of the optic nerve. In this ganglion, which belongs to the vegetative nervous system, there is an interruption of the parasympathetic fibres running from the Yakubovich (Edinger Westfal) nucleus as part of **the oculomotor nerve** to the smooth muscles of the eye (m. sphincter pupillae and m. ciliaris) **the radix oculomotoria**. From three to six **short ciliary nerves** arise from the anterior end of the ganglion which pierce the sclera of the eyeball around the optic nerve and pass inside the eye supplying cornea. The parasympathetic fibres mentioned above pass through these nerves (after their interruption in the ganglion) to the m. sphincter pupillae and m. ciliaris.

V2. The maxillary nerve

The maxillary nerve (n. maxillaris) emerges from the cranial cavity through the foramen rotundum into **the pterygopalatine fossa**; here it is directly continuous with **the infraorbital nerve**

1. The infraorbital nerve (n. infraorbitalis) which passes through **the infraorbital fissure** into **the infraorbital sulcus** and **canal** on the inferior orbital wall and then emerges through **the infraorbital foramen** onto the face (fossa canina of the maxilla) where it ramifies into a bundle of branches. These branches of the infraorbital nerve (**pes anserinus minor**) join partly with the branches of the facial nerve and innervate the skin of the lower eyelid (**rami palpebrales inferiores**), the lateral surface of the nose (**rami nasals externi et interni**) and the upper lip (**rami labials superiores**).

The following branches arise from the maxillary nerve and its con- tinuatitn the infraorbital nerve.

2. The zygomatic nerve (n. zygomaticus) arises in the pterygopalatine fossa, enters the orbit by the inferior orbital fissure, and divides at the back of that cavity (foramen zygomatoco orbitalis) into two branches, **zygomaticotemporal** and **zygomaticofacial,** that follow to the skin of the cheek and the anterior part of the temporal region. It anastomoses with **the lacrimal nerve** (from the first branch of the trigeminal nerve) carrying secretory postganglionic (parasympatetic) fibers for lacrimal gland.

3. The superior dental nerves (nn. alveolares superiors, anteriores, medii et postreriores (enter the tuber maxillae alone)) form a plexus in the thickness of the maxilla **- the superior dental plexus** (plexus dentalis superior) from which superior dental branches arise to the upper teeth (**rami dentales**) and the superior gingival branches to the gums (**rami gingivales**).

4. The ganglionic branches (nn. pterygopalatini), several (two-three) short branches connecting the maxillary nerve with the sphenopalatine ganglion.

The pterygopalatine (sphenopalatine) ganglion (ganglion pterygopalatinum) is located in the pterygopalatine fossa medially and down from the maxillary nerve. In this ganglion, which relates to the vegetative nervous system, the parasympathetic fibres are interrupted; they run from the vegetative nucleus of the of the facial nerve (nucleus salivatorius superior) by nervus pertosus major) to the lacrimal gland and to the mucous glands of the nose and palate.

The sphenopalatine ganglion gives off the following (secretory) branches.

1. Nasal branches (rami nasales posteriores) pass through the sphenopalatine foramen to the mucosal glands of the nose; the largest of these, the **long sphenopalatine nerve** (n. nasopalatinus) passes through the incisive canal to the mucous glands of the hard palate;

2. The palatine nerves (nn. palatini) descend along the greater palatine canal and, after passing through the greater and lesser palatine foramina, innervate the mucosal glands of the hard and soft palates.

In addition to the secretory fibres the nerves arising from the sphenopalatine ganglion contain also sensory nerves (from the second branch of the trigeminal nerve) and sympathetic fibres. Thus, the fibres of the sensory root (the parasympathetic part of the facial nerve) which pass along **the greater superficial petrosal nerve**, through the sphenopalatine ganglion, innervate the glands of the nasal cavity and palate and the lacrimal gland. The last pathway runs from the sphenopalatine ganglion through the ganglionic branches of the maxillary nerve (nn. pterygopalatini) into the zygomatic nerve, and from it through an anastomosis into the lacrimal nerve.

V3. The mandibular nerve

The mandibular nerve (n. mandibularis) contains, in addition to the sensory root, the whole motor root of the trigeminal nerve. The motor root arises from the motor nucleus and passes to the muscles originating from the maxillary arch. As a result the mandibular nerve innervates the muscles attached to the mandible, the skin covering it and other derivatives of the maxillary arch. On emerging from the cranium through **the foramen ovale**, it divides into two groups of branches.

A. Muscle branches.

To the muscles of the same name; **the nerve to the masseter** (n. massetericus), **deep temporal nerves** (nn. temporales profundi), **nerves to the medial and lateral pterygoid muscles** (nn. pterygoidei medialis and lateralis), **nerve to the tensor tympani muscle** (n. tensoris tympani**), nerve to the tensor palati muscle** (n. tensoris veli palatini), **mylohyoid nerve** (n. mylohyoideus); the latter arises from **the inferior dental nerve** (n. alveolaris inferior), a branch of the mandibular nerve and also innervates **the anterior belly of the digastric muscle**.

B. Sensory branches.

1. The buccal nerve (n. buccalis) to the mucosa of the cheek.

2. The lingual nerve (n. lingualis) descends along the medial side of the m. pterygoideus medialis and lies under the mucous membrane of the floor of the oral cavity. After giving off **the sublingual nerve** to the mucosa of the floor of the mouth it innervates the mucosa of **the anterior two thirds** of the back of the tongue. At the place where the lingual nerve passes between both pterygoid muscles, it is joined by a small branch of the facial nerve, **chords tympani**, which emerges from the petrotympanic fissure. It contains parasympathetic secretory fibres that arise from **the superior salivary nucleus** of the facial nerve (synapsing in sublingual and submandibular ganglons) and pass to the sublingual and submandibular salivary glands. It also contains **gustatory fibres** from the first two thirds of the tongue. The fibres of the lingual nerve itself distributed in the tongue are conductors of general sensitivity (sense of touch, pain, and temperature).

3. The inferior dental nerve (n. alveolaris inferior), together with the artery of the same name, passes through **the foramen mandibulae** into **the mandibular canal** where after forming **the inferior dental plexus** it gives off branches to all the lower teeth (**rami dentales**) and gums (**rami gingivales**). At the frontal end of mandibular canal (**foramen mentale**) the inferior dental nerve gives off a thick branch, **the mental nerve** (n. mentalis), which spreads in the skin of the chin (ramus mentalis) and the lower lip (ramus labialis inferior). The inferior dental nerve is a sensory nerve with a small addition of motor fibres which leave it at the foramen mandibulae as part of **the mylohyoid nerve**.

4. The auriculotemporal nerve (n. auriculotemporalis) penetrates into the upper part of the parotid gland and, turning upward, by two roots surround middle meningial artery and passes to the temporal region accompanying the superficial temporal artery. Along the way the nerve gives off secretory branches to the parotid (**rami parotidei**) glands and sensory branches to the temporomandibular articulation (**rami articulares**), to the skin of the anterior part of the concha of the auricle (**rami auriculares anteriores**) and the external acoustic meatus. (**ramus meatus acustici externi**) until ear drum (rr. Membranae tympanici). The terminal branches of the auriculotemporal nerve supply the skin of the temple. (**rami temporales superficiales**)

In the region of the third branch there are branches to the otic ganglion (rr. ranglionare).

The otic ganglion (ganglion oticum), is a small round body located under the foramen ovale on the medial side of the mandibular nerve. It receives parasympathetic secretory fibres in the composition of the lesser superficial petrosal nerve which is a continuation of the tympanic nerve originating from the glossopharyngeal nerve. These fibres are interrupted in the ganglion and pass to the parotid gland by means of the auriculotemporal nerve, with which the otic ganglion is joined.

The facial (7th) nerve

The facial nerve (n. facialis) is a mixed nerve. As a nerve of the second visceral arch it innervates the muscles developing from it, namely, **all the facial-expression** and part of **the sublingual muscles**. It also contains the efferent (motor) fibres emerging from its motor nucleus that pass to these muscles, and the afferent (proprioceptive) fibres arising from their receptors. It includes **gustatory** (afferent) and **secretory** (efferent) fibres belonging to **the n. intermedius** (Wrisberg).

Corresponding to its components, the facial nerve has three nuclei located in the pons varolii: **the motor nucleus** (nucleus [motorius] nervi facialis), the sensory nucleus (**nucleus tractus solitarii**), and the secretory nucleus, superior salivatory nucleus (**nucleus salivatorius superior**). The last two nuclei belong to the **nervus .intermedius**.

The facial nerve emerges to the surface of the brain laterally along the posterior edge of the pons on **the linea trigeminofacialis**, next to the auditory nerve (n. vestibulocochlearis). Then, together with the latter nerve, the facial nerve penetrates **the porus acusticus internus** and enters the canal for the facial nerve (canalis facialis Fallopii). In the canal the nerve first runs horizontally to the outside; then, in the region of the hiatus nervi petrosi major it turns at a right angle to the back and, still lying horizontally, passes along the inner wall of the tympanic cavity in its upper part. It still lies in the bone canal and is separated from the tympanic cavity by a bony plate. Outside of the tympanic cavity the facial nerve again curves and descends vertically, emerging from the cranium through **the foramen stylomastoideum**. In the place where the nerve turns back to form a knee, an right angle (geniculum), its sensory (gustatory) segment forms a small nervous ganglion (**ganglion geniculi**). On emerging from the stylomastoid foramen, the facial nerve runs forward in the substance of the parotid gland, crosses the external carotid artery, and divides behind the ramus of the mandible into branches, from which numerous offsets are distributed over the side of the head, face, and upper part of the neck, supplying the superficial muscles in these regions. The branches and their offsets unite to form the **parotid plexus.** In the canal of the temporal bone the facial nerve gives rise to the following branches:

1. The greater superficial petrosal nerve (n. petrosus major) (secretory nerve) originates in the region of **the genu** and emerges through **the foramen of the greater superficial petrosal nerve**. Then it passes along **the groove of the same name** on the anterior surface of the pyramid of the temporal bone, sulcus n. petrosi majoris, and passes into **the pterygoid canal** together with the sympathetic nerve, **deep petrosal nerve** (n. petrosus profundus) forming with it a common **nerve of the pterygoid canal** (nervus canili pterygoidei Vidii) and reaches the sphenopalatine ganglion. The nerve is interrupted in the ganglion and as rami nasales posteriores and the palatine nerves (nn. palatini) passes to the mucosal glands of the nose and palate; part of the fibres of the zygomatic nerve (from the maxillary nerve) through connections with the lacrimal nerve reach the lacrimal gland.

2. The nerve to the stapedius muscle (n. stapedius) (muscular) innervates the stapedius muscle.

3. The chorda tympani (mixed branch) separates from the facial nerve in the lower part of the facial canal, enters the tympanic cavity, fits there onto the medial surface of the tympanic membrane and then leaves through the fissura petrotympanica. On emerging from the fissure it descends forward and joins the lingual nerve.

The sensory (gustatory) part of the chordae tympani (peripheral processes of cells contained in the ganglion of the facial nerve) as a component of the lingual nerve runs to the mucosa of the tongue supplying its anterior two thirds with gustatory fibres.

The secretory part approaches the submandibular ganglion and after the interruption it supplies the submandibular and sublingual salivary glands with secretory fibres.

After leaving **the foramen stylomastoideum** the following muscle branches separate from the facial nerve.

4. The posterior auricular nerve (n. auricularis posterior) supplies the m. auricularis posterior and venter occipitalis of m. epicranius.

5. The digastric branch (ramus digastricus) supplies the posterior belly of the m. digastricus.

6. The stylohyoid branch (ramus stylohyoideus) supplies m. stylo-hyoideus.

7. Numerous branches to the muscles of expression form **a plexus** in the parotid gland (**plexus parotideus**). In general these branches have a posteroanterior radial direction and, on emerging from the gland, pass to the face and the upper part of the neck, anastomosing widely with the subcutaneous branches of the trigeminal nerve (**pes anserinus major**). Among them are the following branches:

- **the temporal branches** (rami temporales) running to the mm. auriculares anterior and superior, venter frontalis m. epicranius and m. orbicularis oculi;
- **the zygomatic branches** (rami zygomatici) running to the m. orbicularis and m. zygomaticus;
- **the buccal branches** (rami buccales) passing to the muscles in the region of the mouth and nose;
- **the mandibular branch** (ramus marginalis mandibulae) is the branch passing along the edge of the mandible to the muscles of the chin and the lower lip;
- **the cervical branch** (ramus colli) which descends to the neck and innervates the m. platysma. The latter branch constantly anastomoses with the superior branch of the anterior cutaneous nerve of the neck **n. transversus colli** from the cervical plexus (forming the superficial cervical loop – **ansa cervicalis superficialis**).

The sensory root of the facial nerve (n. intermedius), is a mixed nerve. It contains afferent (gustatory) fibres running to its sensory nucleus (nucleus tractus solitarii) and efferent (secretory, parasympathetic) fibres arising from its vegetative (secretory) nucleus (nucleus salivatorius superior). The sensory root (n. intermedius) emerges from the brain as a thin trunk between the facial nerve and the auditory nerve; after passing for a certain distance between both these nerves, it joins the facial nerve and becomes its component. This is why the sensory root (n. intermedius) is referred to as portio intermedia n. facial is. Further on it is continuous with the chorda tympani and the greater superficial petrosal nerve (n. petrosus major). Its sensory fibres arise from the processes of the pseudounipolar cells of the ganglion geniculi. The central processes of these cells together with the n. intermedius pass to the brain and terminate in the nucleus tractus solitarii. The peripheral processes of the cells pass into the chorda tympani conducting gustatory sensitivity from the anterior part of the tongue and the soft palate. The secretory parasympathetic fibres from the n. intermedius begin in the nucleus salivatorius superior and run along the chorda tympani to the sublingual and submandibularglands (by means of the submandibular ganglion) and along the greater superficial petrosal nerve through the sphenopalatine ganglion to the mucosal glands of the nasal cavity and the palate, and to the lacrimal gland. The latter receives its secretory fibres from the n. intermedius through the n. petrosus major, the sphenopalatine ganglion and the anastomosis of the second branch of the trigeminal nerve with the lacrimal nerve.

Thus, the vegetative component of the facial nerve (n. intermedius) innervates **all the glands in the cavities of the face**, with the exception of **the parotid gland** which receives its secretory fibres from **the glossopharyngeal nerve**.

The vestibulocochlearis (8th) nerve

The auditory nerve (n. vestibulocochlearis s. statoacusticus), an afferent nerve which separated away from the facial nerve, contains somatic-sensory fibres running from **the organ of hearing** and **balance**. It consists of two parts **- the vestibular nerve** (pars vestibularis) and **the cochlear nerve** (pars cochlearis), which differ in their functions: the vestibular nerve conducts impulses from the static apparatus laid out in the vestibule and the semicircular canals of the labyrinth of the internal ear, while the cochlear nerve conducts acoustic impulses from the organ of Corti in the cochlea which receives acoustic stimuli.

Since these are all sensory nerves, each of them has its own nerve ganglion containing bipolar nerve cells. The ganglion of the vestibular nerve called **the vestibular ganglion** (ganglion vestibulare) lies on the floor of the internal acoustic meatus, while the ganglion of the cochlear nerve, **spiral ganglion** of the cochlea (ganglion spirale) is located in the cochlea.

The peripheral processes of the bipolar cells of the ganglia terminate in the receptors of the above mentioned parts of the labyrinth. The central processes that emerge from the internal ear through the porus acusticus internus pass as components of the corresponding part of the nerve to the brain. They enter it lateral to the facial nerve reaching their nuclei: the vestibular nerve **- four nuclei** and the cochlear nerve **two nuclei**.

The glossopharyngeal (9th) nerve

The glossopharyngeal nerve (n. glossopharyngeus) is a nerve of the third visceral arch which in the process of development separated from the tenth pair of nerves, the vagus nerve. It consists of three types of fibres: (1) **afferent** (sensory) fibres running from the receptors of the pharynx, the tympanic cavity, mucosa of the tongue (the posterior third), tonsils and palatal arches; (2) **efferent** (motor) fibres innervating one of the muscles of the pharynx (**m. stylopharyngeus**); (3) efferent (**secretory**) fibres, parasympathetic for **the parotid gland**. Corresponding to its components it has three nuclei: **the nucleus tractus solitarii**, to which come the central processes of the cells of two afferent ganglia: **ganglion superius** and **inferius**. The vegetative (secretory) parasympathetic nucleus, **the inferior salivary nucleus** (nucleus salivatorius inferior) consists of cells distributed in the reticular formation around the third nucleus, motor, which is common with the vagus nerve, **nucleus ambiguus**.

The glossopharyngeal nerve with its roots originates from the medulla oblongata behind the olive, above the vagus, and, together with the latter, leaves the cranium through **the foramen jugulare**. Within the limits of the latter the sensory part of the nerve forms a ganglion, **ganglion superius**, and on emerging from the foramen it forms another ganglion, **ganglion inferius**, which lies on the inferior surface of the pyramid of the temporal bone (fossula petrosa). The nerve descends first between the internal jugular vein and the internal carotid artery, and then bends around and behind the m. stylopharyngeus and, along the lateral. side of this muscle, approaches the root of the tongue in a slanting arch where it divides into its terminal branches.

The branches of the glossopharyngeal nerve

1. The tympanic nerve (n. tympanicus) branches away from the ganglion inferius and penetrates the tympanic cavity (**cavum tympani**) where it forms a plexus, **plexus tympanicus**, which receives branches from **the sympathetic plexus** of the internal carotid artery. This plexus innervates the mucous membrane of the **tympanic cavity** and the **auditory tube**. On leaving the tympanic cavity through the superior wall **as the lesser superficial petrosal nerve** (n. petrosus minor), the nerve passes in a sulcus of the same name (**sulcus n. petrosi minoris**) over the anterior surface of the pyramid of the temporal bone and reaches **the otic ganglion**. Through this nerve the otic ganglion receives parasympathetic secretory fibres coming from the inferior salivatory nucleus for the parotid gland. After interruption within the ganglion the secretory fibres reach the gland as part of the auriculotemporal nerve from the third branch of the trigeminal nerve.

2. Branch to the stylopharyngeus (ramus m.. stylopharyngei) to the muscle of the same name.

3. Tonsilar branches (rami tonsillares) to the mucosa of **the palatine tonsils and arches**.

4. Pharyngeal branches (rami pharyngei) to **the pharyngeal plexus** (plexus pharyngeus).

5. Lingual branches (rami linguales) the terminal branches of the glossopharyngeal nerve, to the mucosa of **the posterior third** of the tongue supplying it with sensory fibres, among which the **gustatory** fibres also pass to the papillae vallatae.

6. Branch to the carotid sinus (ramus sinus and glomus carotici) is a sensory nerve to the carotid sinus (glomus caroticum).

The vagus (10th) nerve

The vagus nerve (n. vagus) developed from the fourth and subsequent visceral arches. It was given such a name because it is the longest of the cranial nerves. With its branches the vagus nerve supplies the respiratory organs, a considerable part of the digestive tract (up to the colon sigmoideum) and also gives off branches to the heart which receives fibres that slow down the heart beat. The vagus nerve consists of three types of fibres.

Afferent (sensory) fibres emerging from the receptors of internal organs and vessels described above, as well as from a certain part of **the dura mater** and **the external auditory meatus** with the concha auriculae to the sensory nucleus, nucleus tractus solitarii.

Efferent (motor) fibres for striated muscles of the pharynx, the soft palate and the larynx and the afferent (proprioceptive) fibres arising from the receptors of these muscles. These muscles receive fibres from the motor nucleus (**nucleus ambiguus**).

Efferent (parasympathetic) fibres originating in the vegetative nucleus—**the dorsal nucleus of the vagus nerve** (nucleus dorsalis n. vagi). They run to the striated muscles of the heart (slowing down the heart beat) and to the smooth muscles of the vessels (dilating vessels). Moreover, the cardiac branches of the vagus nerve include the n. depressor which is a sensory nerve for the heart itself and the initial segment of the aorta and is concerned with the reflex control of blood pressure. The parasympathetic fibres also innervate the trachea and lungs (they constrict the bronchi), oesophagus, stomach, and intestine up to the colon sigmoideum (intensify peristalsis), the glands situated in these organs and the glands of the abdominal cavity: liver, pancreas (secretory fibres), and kidneys.

The parasympathetic portion of the vagus nerve is very large and as a consequence it is predominantly a vegetative nerve, very important for the vital functions. The vagus nerve is a complex system consisting not only of nerve conductors of various origin, but one that contains nerve ganglia in its trunk.

Fibres of all kinds connected with the three main nuclei of the vagus nerve arise from the medulla oblongata. They pass into its sulcus lateralis posterior below the glossopharyngeal nerve in ten to fifteen roots which form the thick trunk of the nerve. This trunk together with **the glossopharyngeal** and **accessory nerves** leaves the cranium through **the foramen jugulare**. In the jugular orifice the sensory part of the nerve forms a small ganglion (**ganglion superius**) and on leaving this orifice it forms another fusiform swelling, the **ganglion inferius**. Both ganglia contain pseudounipolar cells whose peripheral processes are components of the sensory branches running to these ganglia from receptors of the internal organs and vessels (ganglion inferius) and the external auditory meatus (ganglion superius); the central processes group together in a singular bundle which ends in the sensory nucleus (nucleus tractus solitarii).

On leaving the cranial cavity, the vagus nerve descends to the neck behind the vessels into a groove, first between the internal jugular vein and internal carotid artery, and then lower between the same vein and the common carotid artery; it lies in the same sheath as the vessels mentioned above. Further the vagus nerve enters through **the superior thoracic aperture** into the thoracic cavity where its **right trunk** lies in front of **the subclavian artery**, while the **left trunk** extends on the anterior surface of **the aortic arch**. Descending further, both vagus nerves by-pass the root of the lung on both sides dorsally, and then accompany the oesophagus, forming plexuses on its walls; the left nerve runs along the anterior surface and the right nerve along the posterior surface. Together with the oesophagus both vagus nerves pass through **the oesophageal hiatus** into **the abdominal cavity** where they form plexuses on the stomach walls. The trunks of the vagus nerves in the uterine period are arranged symmetrically along the sides of the oesophagus. After the stomach turns from left to right the **left vagus migrates forward** and **the right vagus backward** and, as a result, **the left vagus** branches out on the **anterior surface**, while the **right vagus on the posterior surface**.

In its initial portion the vagus nerve joins the glossopharyngeal nerve, the accessory nerve, the hypoglossal nerve and the superior ganglion of the sympathetic trunk. The vagus nerve gives rise to the following branches.

A. In the cranial part (between the beginning of the nerve and the inferior ganglion):

1. The meningeal branch (ramus meningeus) to the dura mater of the posterior cranial fossa.

2. The auricular branch (ramus auricularis), to the posterior wall of the external auditory meatus and to part of the skin of the concha auriculae. This is the **only cutaneous branch** from the cranial nerves that bears no relation to the trigeminal nerve.

B. In the cervical part:

1. Pharyngeal branches (rami pharyngei) together with branches of the glossopharyngeal nerve and sympathetic trunk form a plexus (**plexus pharyngeus**). The pharyngeal branches of the vagus nerve supply **the constrictor muscles of the pharynx (**constrictor pharynges superior et medius**),** the muscles of palatin arches (mm. palatoglossus et palatopharyngeus) and soft palate (with **the exception** of **tensor veli palatini**). The pharyngeal plexus also gives rise to sensory fibres running to the mucosa of the pharynx.

2. The superior laryngeal nerve (n. laryngeus superior) supplies sensory fibres to the laryngeal mucosa above the level of **the rima** glottidis, part of the root of the tongue and the epiglottis (internal branch), and sends motor fibres to part of the laryngeal muscles (m. crocothiroideus) and **the lower constrictor muscle of the pharynx**. (external branch)

3. The upper cardiac branches (rami cardiaci cervicales superiores) often emerge from the superior laryngeal nerve and are distributed in the cardiac plexus. **N. depressor** is a component of the branches.

C. In the thoracic part:

1. The recurrent laryngeal nerve (n. laryngeus recurrens) branches off where the vagus nerve lies in front of **the aortic arch** (on the left) and in front of **the subclavian artery** (on the right). On the right side this nerve curves around the subclavian artery from below and from the back, and on the left side it curves around the aortic arch also from the back and from below. After this it ascends in the groove **between the oesophagus** and **the trachea** supplying them with numerous branches, **oesophageal branches** (rami esophagei) and **tracheal branches** (rami tracheales). The end of the nerve known as **lower laryngeal nerve** (n. laryngeus inferior) innervates **some of the laryngeal muscles, the mucosa of the larynx** below the vocal chords, an area of the mucous membrane of the root of the **tongue** near the epiglottis, and also **the trachea**, **throat** and **oesophagus**, the **thyroid gland and thymus**, the lymph nodes of the neck, heart and mediastinum. It is connected with the neighbouring nerves, sympathetic ganglia and perivascular plexuses.

2. Cardiac branches (lower) (ramus cardiaci cervicales inferiores) usually consist of two branches which arise from the recurrent laryngeal nerve and the thoracic portion of the vagus nerve and pass to the cardiac plexus./

3. Pulmonary and tracheal branches (rami bronchiales and tracheales) together with the branches of the sympathetic trunk form the pulmonary plexus on the walls of the bronchi. The smooth muscles and glands of the trachea and bronchi are innervated by the branches of this plexus and, moreover, it also contains sensory fibres for the trachea, bronchi and lungs.

4. Thoracic cardiac branches (rami cardiaci thoracici).

5. Oesophageal branches (rami esophagei) run to the wall of the oesophagus.

6. Small branches to the thoracic duct.

D. In the abdominal part:

The plexuses of the vagus nerves running along the oesophagus continue onto the stomach forming well-defined **vagal trunks** (trunci vagales) (**anterior and posterior**). Each vagal trunk is a complex of nerve conductors not only of the parasympathetic, but also of the sympathetic and afferent animal nervous systems, and contains fibres of the vagus nerves.

The continuation of the left vagus nerve which descends from the anterior side of the otgophagus to the anterior wall of the stomach forms a plexus (**plexus gastricus anterior)** located mainly along **the leser curvature** from which anterior gastric branches (**rami gastrici anteriores**) mixed with sympathetic branches arise to the wall of the stomach (to the muscles, glands and mucous membrane). Some small branches pass to **the liver** (rami hepatici) through the lesser omentum. The **right n. vagus** also forms a **plexus on the posterior** wall of the stomach (**plexus gastricus posterior)** in the region of the small curvature. This plexus gives off **posterior gastric branches**; besides, the greater part of its fibres, **coeliac branches** (rami celiaci) follow the tract of a. gastrica sinistra to the coeliac ganglion, and from there along the vascular branches together with the sympathetic plexuses to the liver, spleen, pancreas, kidneys, small and large intestine up to the sigmoid colon. In cases of unilateral or partial damage to the tenth nerve the disorders concern mainly its animal functions. Disorders of visceral innervation may be comparatively mildly manifested. This is explained first by the fact that in innervation of the internal organs there may be zones of overlapping, and, second, that the peripheral segments of the vagus nerve contain nerve cells, i.e. vegetative neurons, which play a role in the automatic control of the function of internal organs.

The accessory (11th) nerve

The accessory nerve (n. accessorius) develops in association with the last visceral arches; it is a muscle nerve, contains efferent (motor) and afferent (proprioceptive) fibres and has two motor nuclei lodged in the medulla oblongata and the spinal cord. According to these nuclei, the cerebral and spinal portions are distinguished. **The cerebral portion** arises from the medulla oblongata immediately below the vagus nerve. **The spinal portion** of the accessory nerve forms between the anterior and posterior roots of the spinal nerves (C2-05) and partly from the anterior roots of the three superior cervical nerves. It ascends as a small nervous trunk (by **foramen magnum**) and joins the cerebral portion. Since the accessory nerve is a part that separated from the vagus nerve, it emerges together with the vagus from the cranial cavity through **the foramen jugulare**, and preserves connection with it by means of the internal branch, the accessory branch to the vagus nerve (**ramus**

internus). Another branch, external, of the accessory nerve, the branch to the sternocleidomastoid muscle (**ramus externus**) innervates **the trapezius muscle** and **sternocleidomastoid muscles** that separated from it. The cerebral portion of the accessory nerve as a component of the recurrent laryngeal nerve innervates the muscles of the larynx.

The spinal portion of the accessory nerve participates in the motor innervation of the pharynx reaching its muscles as part of the vagus nerve from which the accessory nerve separated incompletely.

The common features and closeness of the accessory and the glossopharyngeal nerves with the vagus nerve is explained by the fact that the ninth, tenth and eleventh pairs of cranial nerves constitute one group of branchial nerves, the vagus group from which the ninth nerve emerged and the eleventh nerve separated.

The hypoglossal (12th) nerve

The hypoglossal nerve (n. hypoglossus) is a muscle nerve containing efferent (motor) fibres to the muscles of the tongue and afferent (proprioceptive) fibres from the receptors of these muscles. It also contains sympathetic fibres from the superior cervical sympathetic ganglion; it has connections with the lingual nerve, with the inferior ganglion of the vagus nerves, and with the first and second cervical nerves.

The only somatic-motor nucleus of a nerve laid down in the medulla oblongata, in the region of the **trigonum of the hypoglossal nerve** of the rhomboid fossa, descends through the medulla oblongata to the first-second cervical segment; it is a component of the reticular formation system. Appearing on the base of the brain **between the pyramid and olive by several roots**, the nerve then passes through **the hypoglossal canal** of the occipital bone, canalis (nervi) hypoglossi, descends along the lateral side of the a. carotis interna, runs under the posterior belly of the m. digastricus and proceeds in the form of an arch, with convexity down, along the lateral surface of the m. hyoglossus. Here the arch of the hypoglossal nerve limits **Pirogoff's triangle** at the top.

In a high position of the arch of the hypoglossal nerve Pirogoff's triangle has a larger area, and vice versa. At the anterior edge of the m. hyoglossus the hypoglossal nerve separates into its terminal branches which enter the muscles of the tongue.

One of the branches of the nerve, **radix superior**, descends to join the radix inferior of the cervical plexus so that they both form **the ansa cervicalis hypoglossi** (ansa cervicalis), which innervates the muscles located under the hyoid bone and m. geniohyoideus. The radix superior of the hypoglossal nerve consists entirely of the fibres of the **first and second cervical nerves** which came to join it from the cervical plexus. This morphological connection of the hypoglossal nerve with the cervical plexus can be explained by the development of the nerve, and also by the fact that the muscles of the tongue in the act of swallowing are functionally closely connected with the muscles of the neck which affect the hyoid bone and the thyroid cartilage.

Terminal nerve

The terminal nerve is arguably the most rostral cranial nerve. Its bipolar neurons have free nerve endings that are located in the nasal mucosa, but their modality (possibly chemosensory) has not been established. These neurons project to several sites in the ventral and medial regions of the forebrain, including **the septum, olfactory tubercle, and preoptic area**. The terminal nerve neurons contain the reproductive hormone, luteinizing hormone-releasing hormone, and may be involved in the regulation of reproductive behavior.

Peripheral innervation of the soma

The fibers of each nerve are distributed within the boundaries of a definite area of skin or muscle as a result of which the whole skin and all the muscles can be subdivided into zones, i.e. regions of the ramification of the given cutaneous or muscle nerve. Such innervation is called peripheral, or zonal. Knowledge of it is very important in establishing diagnosis in affection of the nerves.

Segmental innervation

In accordance with the segmental structure of the body, each nerve segment (neuromere) is connected with the corresponding body segment (somite). Each posterior root of a spinal nerve and each spinal ganglion are therefore concerned with innervation of that area of skin (dermatome) which is connected with it during embryonic development. In exactly the same manner each anterior root innervates those muscles which arose together with it from the given segment (myotome) and form with it the neuromuscular segment. As a result, the entire skin and all the muscles can be divided into a number of successive root zones, or girdles, innervated by. the corresponding posterior or anterior nerve roots. This is the root, or segmental innervation of the body. As distinct from the peripheral innervation zones of the cutaneous nerves, the zones of root innervation are marked by a specific feature consisting in the fact that fibres related to one posterior root or one segment, even if they are components of different nerves, supply a definite continuous area of skin corresponding to the whole given neural segment, or root, and termed therefore the root zone. The root, or segmental, zones of sensory innervation run on the skin in bands, or girdles. That is why segmental sensory disorders are easily distinguished from peripheral disorders in typical cases. In inflammation of the posterior root (radiculitis), for instance, girdle pain or herpes zoster develops corresponding exactly to the given root zone (girdle) of the skin.

In practice, it is important to know that the neighbouring nerve segments fully overlap one another as a result of which each skin segment is innervated by three adjacent nerve segments. No sensory disorders are therefore detected in transection of one of the roots. For sensitivity to be lost in one segment of the skin, three neighbouring nerve roots must be cut, which should be borne in mind when performing an operation. The superimposition of the segments should also be taken in consideration in establishing the boundaries of the spinal process; they should be marked one or two segments above the line of the skin anaesthesia.

Nerve distribution patterns

1. In accordance with the grouping of the body around the nervous system, the nerves spread out laterally **from the midline** on which the central nervous system (the spinal cord and brain) is situated.

2. In accordance with the bilateral symmetry principle of the body structure, the nerves are paired and run **symmetrically**.

3. In accordance with the metameric structure of **the trunk**, the nerves in this region **maintain a segmental structure** (the intercostal, ilio-inguinal, and iliohypogastric nerves).

4. The nerves stretch for **the shortest distance** from the site of emergence from the spinal cord or brain to the organ. This explains the origin of the short branches to the closely located organs and the long branches to remote organs, which, however, run approximately on a straight line, e.g. the sciatic nerve.

In migration of the organ from the place where it had been primarily laid down to the site of its final location after birth, **the nerve grows and follows it.**

5. The nerves of muscles arise from spinal segments corresponding to the myotomes which had given origin to the given muscle. That is why even when the muscle later changes its position, it receives innervation from the source situated close to the site of the primary germ. This explains why **the truncipetal muscles** of the trunk, which had migrated to it from the head, are innervated from the cranial nerves (the accessory nerve) and those which had moved from the neck are innervated from the cervical plexus, or why **the truncifugal muscles** of the limbs are supplied with innervation from the main nerve plexus of the given limb, i.e. the shoulder girdle muscles are innervated from the brachial plexus. The same circumstance explains why the diaphragm, laid down on the neck, is innervated from the phrenic nerve originating from the cervical plexus.

The site of the embryonic development of an organ can therefore be determined according to the site of the origin of the nerve because a conformity exists between the origin of the nerve and the site where the organs are laid down.

6. A muscle formed from **fusion** of several myotomes is innervated by **more than one nerve** (e.g. innervation of the broad abdominal muscles by the intercostal nerves and branches of the lumbar plexus). The same is encountered in relation to the visceral muscles which develop from several visceral arches. For instance, the anterior belly of the digastric muscle derived from the first visceral arch is innervated by the trigeminal nerve, while the posterior belly, a derivative of the second visceral arch, is innervated by the facial nerve.

7. The superficial (**cutaneous**) nerves pass in attendance to the subcutaneous veins; the deep nerves run with the arteries, veins, and lymphatic vessels and form neuromuscular bundles with them.

8. The nerves lodged in **the neurovascular bundles**, like the bundles themselves, are located on the flexor surfaces of the given body region in protected and covered pla

vegetative (autonomic) nervous system

The fundamental qualitative difference in the structure, development and action of the smooth and striated musculature has been pointed out above. The skeletal muscles take part in the organism's reaction to environmental factors and respond by rapid and purposeful movements to changes in the environment. The smooth musculature is located in the viscera and vessels and works slowly but rhythmically, thus ensuring the course of vital processes in the body. These functional differences are linked with the difference in innervation: the skeletal musculature receives motor impulses from the animal or somatic part of the nervous system, whereas the smooth musculature receives them from the vegetative or autonomic part.

The vegetative nervous system controls the activity of all organs concerned with the vegetative functions of the body (nutrition, respiration, excretion, reproduction, and fluid circulation) and accomplishes trophic innervation.

The trophic function of the vegetative nervous system is responsible for the nutrition of the tissues and organs in conformity to their functioning under certain environmental conditions (adaptational-trophic function).

It is general knowledge that changes in the state of the higher nervous activity affect the function of the viscera and vice versa, changes in the organism's internal environment cause an effect on the functional state of the central nervous system. The vegetative nervous system intensifies or weakens the function of the specifically working organs. This regulation is of a tonic character and the vegetative system alters therefore the tonus of the organ. Since one and the same nerve fibre acts only in one direction and is incapable of simultaneously increasing and reducing the tonus, the vegetative nervous system is accordingly separated into two parts, or systems: **the sympathetic** and **parasympathetic systems.**

The sympathetic part is mainly concerned with **trophic functions**. It is responsible for intensification of oxidation processes, nutrient consumption, and respiration and increases the rate of cardiac activity and the supply of oxygen to the muscles.

The parasympathetic system carries a **protective role**: constriction of the pupil in bright light, inhibition of cardiac activity, evacuation of the cavitary organs.

Comparison of the areas of distribution of the sympathetic and parasympathetic innervation discloses, firstly, the predominant role of one vegetative part over the other. The urinary bladder, for instance, receives mostly parasympathetic innervation, and division of the sympathetic nerves causes no essential changes in its activity; the sweat glands, the pilary muscles of the skin, the spleen, and the suprarenals are supplied only with sympathetic innervation. Secondly, in organs with double vegetative innervation, interaction of **the sympathetic and parasympathetic nerves** in the form of **a definite antagonism** is encountered. Stimulation of the sympathetic nerves causes dilatation of the pupil, constriction of the vessels, an increase in the rate of cardiac contractions, and inhibition of intestinal peristalsis; stimulation of the parasympathetic nerves, in contrast, leads to constriction of the pupil, dilatation of the vessels, diminution of the heart beat rate, and intensification of peristalsis.

The “**antagonism**” of the sympathetic and parasympathetic systems, however, should not be considered static, as an opposition of their functions. There are reciprocally acting systems and the relations between them alter dynamically in the different phases of the functioning of this or that organ; they can act both as antagonists and as **synergists**.

Antagonism and synergism are two aspects of a single process. The normal functions of our organism is ensured by the coordinated action of these two parts of the vegetative nervous system. This coordination and regulation of functions is brought about by the cerebral cortex.

The sympathetic and parasympathetic parts are distinguished in the vegetative system mainly according to the physiological and pharmacological data, but morphological distinctions due to their structure and development also exist.

We shall therefore first characterize the morphological features of the vegetative nervous system as compared to those of the somatic nervous system. We describe firstly **the centres** of the vegetative nervous system.

The somatic nerves emerge from the brainstem and spinal cord segmentally for the whole length of these structures. The segmental character is also maintained partly on the periphery.

The vegetative nerves emerge only from some of the parts (foci, centers) of the central nervous system. Four such foci exist.

1. The mesencephalic part located in the midbrain (the accessory, or Yakubovitch's nucleus, nucleus accessorius, and the unpaired median nucleus of the third pair of cranial nerves).

2. The bulbar part located in the medulla oblongata and pons (the nuclei of the seventh, ninth, and tenth pairs of cranial nerves). Both parts are united under the term cranial part.

3. The thoracolumbar part situated in the lateral horns of the spinal cord for the distance of the C8 - L3 segments.

4. The sacral part located in the lateral horns of the spinal cord for the distance of the S2-S4 segments.

The thoracolumbar part belongs to **the sympathetic system**, the cranial and sacral parts to **the parasympathetic system**.

Higher vegetative centres dominate over the foci; these centres are not simply sympathetic or parasympathetic but are concerned with the regulation of both parts of the vegetative nervous system. They are **suprasegmental centers** and are situated in the brainstem and pallium as follows.

1. In the metencephalon: the vasomotor centre on the floor of the fourth ventricle; **the cerebellum** to which regulation of some of the vegetative functions (vasomotor reflexes, skin trophies, the rate of wound healing, etc.) is attributed.

2. In the midbrain: the grey matter of the aqueduct of Sylvius.

3. In the diencephalon: the hypothalamus (tuber cinereum).

4. In the telecephalon: the striated body, insula, prahippocampus uncus.

The hypothalamic region is the most essential in vegetative regulation; it is one of the oldest parts of the brain though older and phylogenetically younger structures are distinguished in it.

The nuclei of the hypothalamic area are connected through the hypothalamo-hypophyseal connection with the hypophysis to form the hypothalamo-hypophyseal system. This system, acting by means of the hypophyseal incretions, is a regulator of all the endocrine glands.

The hypothalamic region regulates the activity of all organs of vegetative life by uniting and coordinating their functions using the nervous and endocrine systems.

The vegetative and somatic functions of the whole body are united in the cerebral cortex, in the premotor zone in particular. The cortex is a complex of the cortical ends of the **analysers** and it receives stimuli from all organs, the organs of vegetative life among others, producing an effect on them through its efferent systems, those of the vegetative nervous system included. Consequently, a two-way connection exists between the cortex and the viscera, i.e. a **cortico-visceral connection.** As a result, all vegetative functions are subordinate to the cerebral cortex which directs all body processes.

The vegetative nervous system is thus not an independently functioning autonomic structure, a it is a special part of the integrate nervous system to whose highest parts, the cerebral cortex among others, it is subordinate. Therefore, like in the somatic part of the nervous system, **a central** and **peripheral part** can be distinguished in it.

The central part are the above described foci and centres in the spinal cord and brain.

The peripheral part is composed of the nerve ganglia, nerves, plexuses, and peripheral nerve endings.

The reflex arc of vegetative system differs from somatic one. The cell body of **the sensory neuron**, both of the somatic and of the vegetative nervous systems, is located in the spinal ganglion (ganglion spinale) in which afferent pathways, both from organs of somatic life and those of vegetative life, gather and which is therefore a mixed somatic vegetative ganglion.

The cell body of the internuncial neuron of the vegetative nervous system, as distinct from that of the somatic system, is located in **the lateral horns** of the spinal cord. The axon of a somatic internuncial neuron arises from the cells of the posterior horn and terminates within the boundaries of the spinal cord among the cells of its anterior horns.The internuncial neuron of the vegetative system, in contrast, does not terminate in the spinal cord but passes from it to **nerve ganglia** lying on the periphery. On emerging from the spinal cord the axon of the internuncial neuron runs into the ganglia of the sympathetic trunk (ganglia trunci sympathici) related to the sympathetic part of the vegetative nervous system (these are ganglia of the first order, they form the sympathetic trunk), or the fibres do not terminate in these ganglia but stretch to the intermediate ganglia (ganglia intermedia) lying closer to the periphery between the sympathetic trunk and an organ (e.g. the mesenteric ganglia). These are ganglia of the second order and are also related to the sympathetic nervous system. Finally, the fibres may reach, without interruption, ganglia lying either near to an organ (**paraorganic** ganglia, e.g. the ciliary, optic ganglia, and others) or within the organ (**intraorganic**, **intramural** ganglia); both are ganglia of the third order and are called the terminal ganglia (ganglia terminalia). They are related to the parasympathetic part of the vegetative nervous system. All fibres which stretch to the ganglia of the first, second, or third order and are axons of an internuncial neuron are called **preganglionic fibres** (rami preganglionares). They are covered with myelin.

The third, **effector neuron** of the somatic reflex arc is located in the anterior horns of the spinal cord, whereas the effector neuron of the vegetative reflex arc was brought out of the central into **the peripheral nervous system** in the process of development, closer to the working organ, and is located **in the vegetative nerve ganglia.** This positioning of the effector neurons on the periphery is responsible for the main sign of the vegetative nervous system, namely the double-neurone structure of the efferent peripheral pathway: the first is the internuncial neuron whose body lies in the vegetative nuclei of .the cranial nerves or in the lateral horns of the spinal cord while its axon runs to a ganglion; the second is the efferent neuron with the body located in the ganglion and the axon reaching the working organ. The effector neurons of the sympathetic nerves arise in the ganglia of the sympathetic trunk (ganglia of the first order) or in the intermediate ganglia (ganglia of the second order); the effector neurons of the parasympathetic nerves originate in the para- or intraorganic ganglia, the terminal ganglia (ganglia of the third order). Since there is synapsis of the internuncial and efferent neurones in these ganglia, the indicated difference between the sympathetic and parasympathetic parts of the vegetative nervous system is linked exactly with these neurons.

The axons of the efferent vegetative neurons are almost devoid of myelin, they are amyelineted. They constitute **the postganglionic fibres** (rami postganglionares). The postganglionic fibres of the sympathetic nervous system which arise from the ganglia of the sympathetic trunk diverge in two directions. Some pass to the viscera and form the visceral part of the sympathetic system. Other fibres form the communicating branches (**rami communicantes grisei**) connecting the sympathetic trunk with the somatic nerves. As components of these nerves, the fibres reach the somatic organs (the motor apparatus and the skin) in which they innervate the smooth muscles of the vessels and nerves, and the glands.

The sum total of the described efferent vegetative fibres stretching from the ganglia of the sympathetic trunk to the organs of the soma form the somatic part of the sympathetic system. Such structure provides for the functioning of the vegetative nervous system which regulates the metabolism of all parts of the organism in conformity with the continuously changing environmental conditions and with the activity (work) of the organs and tissues.

In accordance with this most universal function associated with all parts, all organs and tissues of the body and not simply with separate organs and tissues, the vegetative nervous system is characterized morphologically also by universal, generalized distribution in the body, and penetrates all organs and tissues.

Therefore, the sympathetic nervous system innervates not only the viscera but also the soma in which it is responsible for the metabolic and trophic processes.

The visceral part of the sympathetic system contains all these three types of nerves for the viscera, whereas the somatic part of this system contains only vasomotor and trophic nerves. As to the functional nerves for the organs of the soma (the skeletal musculature, etc.) these pass as components of the somatic nervous system.

The main distinction of the efferent part of the vegetative nervous system from the efferent part of the somatic nervous system consists therefore in the fact that the somatic nerve fibres on emerging from the central nervous system, pass to the working organ without interruption, whereas the vegetative fibres are interrupted on their way from the brain to the working organ in one of the ganglia of the first, second or third order. As a consequence, the efferent tract of the vegetative system breaks up into two parts of which it is actually composed: the preganglionic myelinated fibres, rami preganglionares, and postganglionic devoid of myelin fibres, rami postganglionares.

The presence of ganglia in the efferent part of the reflex arc is a characteristic sign of the vegetative nervous system, distinguishing it from the somatic system.

The nerves also possess certain characteristic features. The afferent pathways of the vegetative nervous system do not possess the character of macroscopically visible nerves and their fibres pass as components of other nerves (the greater and lesser splanchnic nerves, the posterior roots, etc.). The sympathetic system in this case is marked by the fact that the sensory innervation associated with it can spread extensively and, consequently, the sympathetic system can be regarded as a system of collateral innervation.

For instance, the afferent spinal nerve fibres contributing to the formation of the solar plexus that innervates the abdominal organs arise from numerous spinal ganglia (C5-L3). This circumstance determines the multiplicity and the multisegmental nature of the pathways and sources of afferent innervation of the abdominal organs. This also explains the conduction of the sense of pain from the viscera both along the vegetative and the somatic nerves. Among the sources and pathways of afferent innervation of the viscera, principal and additional ones can therefore be distinguished. This division is intimately related to the concept of collateral pathways of afferent spinal innervation of the viscera. In morbid conditions (interruption of the spinal cord, etc.), the collateral pathways may act as compensatory pathways substituting for the activity of the impaired main pathways, as compensatory adaptations in the form of an "overlap" in the afferent innervation of the organs.

As to the efferent pathways of the vegetative system, these form clearly defined nerves and ganglia. One can therefore speak about two centrifugal pathways of the integral nervous system: one is the somatic, motor nerves, and the other is the vegetative nerves. The vegetative nerves form plexuses around the blood vessels with which they approach and enter the organs. The presence of plexuses around the vessels is a characteristic sign of the vegetative nervous system distinguishing it from the somatic system.

As it is indicated above, the vegetative nervous system is characterized by universal distribution in the body. It has an extensive area of efferent innervation embracing all the body organs and tissues, including the skeletal musculature (whose tonus it increases). This constitutes the morphological feature of the vegetative nervous system in contrast to the somatic system whose centrifugal fibres innervate only the skeletal muscles, i.e. it has a relatively limited area of efferent innervation.

To understand the structure of the vegetative nervous system its development must be taken into account.

The smooth musculature of the invertebrates is regulated by the ganglionic-reticular nervous system which, in addition to this function, is also concerned with metabolism regulation. Since it adapts the level of metabolism to the altering activity of the organs, this function of the nervous system is called adaptive while the corresponding function of the nervous system is called adaptative-trophic. It is the most common and extremely old function of the nervous system, which had existed in the primitive ancestors of the vertebrates. In the later process of evolution, the motor apparatus (the hard skeleton and striated muscles) and the sensory organs, i.e. the organs of animal life, developed most prominently. Consequently, the part of the nervous system concerned with these organs, i.e. the somatic part, underwent the most striking changes and acquired new signs, namely, the fibres were isolated by means of myelin sheaths (myelinited fibres) and the rate of stimulation conduction increased (12-100 m/sec). In contrast, the organs of vegetative life went through a slower and less progressive evolution so that the part of the nervous system linked with them reserved for itself the most common function, the adaptation-trophic. This is the vegetative part of the nervous system.

Along with certain specialization, it retained a number of the old primitive features: the absence of myelin sheaths in most nerve fibres (non-medullated fibres), a lower rate of stimulation conduction (0.3-10 m/sec), and a lesser concentration and centralization of the effector neurons remaining scattered on the periphery as components of ganglia, nerves, and plexuses. The effector neuron proved to be located close to or even inside the working organ. Such peripheral location of the effector neuron on the periphery was responsible for the main morphological feature of the vegetative nervous system, namely, the double-neuron structure of the efferent peripheral pathway consisting of an internuncial and an effector neurons.

With the appearance of the spinal (truncal) medulla, the adaptation impulses arising in it pass along the internuncial neurons which are marked by a high rate of stimulation, but adaptation itself is accomplished by the smooth muscles and glands which are reached by effector neurons marked by slow conduction (which is pointed out above). This contradiction has been corrected during evolution by the development of special nerve ganglia in which contact is established between the internuncial and effector neurons; one internuncial neuron communicates with many effector neurons (approximately 1 : 32). As a result the medullated fibres possessing a high rate of stimulation conduction are switched over to the non-medullated fibres of a small conduction rate. The whole efferent peripheral pathway of the vegetative nervous system is thus divided into two parts: preganglionic and postganglionic, while the ganglia themselves become the transformers of rapid to slow stimulation rates.

The brain forming in lower fishes has centres which unite the activity of organs producing the organism's internal environment.

Since the skeletal striated musculature takes part in this activity, in addition to the smooth musculature, the need arises for coordinating their work. For instance, the gill opercles are brought into action by the skeletal muscles; in man likewise both the smooth muscles of the bronchi and the striated muscles of the chest participate in the act of respiration. This coordination is accomplished by a special reflex apparatus developing in the metencephalon as a system of the vagus nerve (the bulbar part of the parasympathetic nervous system).

Other structures also develop in the central nervous system, which, like the vagus nerve, are responsible for the coordinated mutual activity of the skeletal muscles (which possess high rates of stimulation) and the smooth muscles (possessing low stimulation rates). Among such structures is the part of the oculomotor nerve which by means of the smooth and striated muscles of the eye sets the standard width of the pupil, accommodation, and convergence according to the intensity of the illumination and the distance to the object examined, in the same manner as it is done by a photographer (the mesencephalic part of the parasympathetic nervous system). Another such structure is the part of the sacral nerves (second, third, and fourth) which is responsible for the common function of the pelvic organs (the rectum and bladder), i.e. evacuation, accomplished by the joint action of the smooth muscles of these organs and the striated muscles of the pelvis and the prelum abdominale (the sacral part of the parasympathetic system). A central adaptation apparatus developed in the midbrain and diencephalon in the form of grey substance arranged around the aqueduct and tuber cinereum (the hypothalamus).

Finally, centres uniting the higher somatic and vegetative functions formed in the cerebral cortex.

The development of the vegetative nervous system in **ontogenesis** (embryogenesis) differs from that in phylogenesis.

The vegetative part of the nervous system arises from a source in common with the somatic part, namely from the neuroectoderm, which proves the unity of the whole nervous system.

Sympathetoblasts evicted from the common germ of the nervous system migrate to the periphery, and accumulate in definite places to form at first the ganglia of the sympathetic trunk and then the intermediate ganglia as well as the nerve plexuses. The processes of the cells of the sympathetic trunk unite into bundles to form the grey communicating branches (rami communicantes grisei).

The cephalic part of the vegetative nervous system develops in a like manner. The germs of the parasympathetic ganglia are evicted from the medulla oblongata or the ganglionic lamina, migrate for a far distance along the branches of the trigeminal, vagus, and other nerves and settle on them or form intramural ganglia.

The sympathetic nervous system

The sympathetic nervous system occurs historically as a segmental part and therefore in man it also has a segmental structure.

The central part of the sympathetic system is located in the lateral norns of the spinal cord between the level of C8 and L3 in the intermediolateral nucleus (nucleus intermediolateralis). It gives rise to fibres innervating the smooth muscles of the viscera and the sensory organs (eyes), and the glands. Vasomotor, pilomotor, and perspiration centres are also located here. It is considered (and has been verified by clinical experience) that different parts of the spinal cord cause a trophic effect and have influence on thermoregulation and metabolism.

The peripheral part of the sympathetic system is firstly formed of two symmetrical **right and left sympathetic trunks** (truncus sympathicus dexter and sinister) stretching on either side of the spine from the base of the skull to the coccyx where the caudal ends of both trunks meet to form a single common ganglion. Each sympathetic trunk is composed of a series of nerve ganglia of the first order connected by longitudinal **interganglionic branches** (rami interganglionares) that consist of nerve fibres. In addition to the ganglia of the sympathetic trunk (ganglia trunci sympathici), the intermediate ganglia mentioned above are also constituents of the sympathetic system. It has also been found that beginning from the level of the superior cervical ganglion the sympathetic trunk contains elements of the parasympathetic and even those of the somatic nervous system.

The processes of cells located in the lateral horns of the thoracolumbar part of the spinal cord emerge from it through the anterior roots and, on separating from them, pass in **the white communicating branches** (rami communicantes albi) to the sympathetic trunk. Here they join by means of synapsis with the cells of the sympathetic trunk ganglia or pass through the ganglia without interruption and reach one of intermediate ganglia. This is the preganglionic pathway. From the ganglia of the sympathetic trunk or (if there was no interruption) from the intermediate ganglia arise non-medullated fibres of the postganglionic pathways and pass to the blood vessels and viscera.

Since the sympathetic system has a somatic part, it is connected with the spinal nerves providing innervation of the soma. This connection is brought about by the grey communicating branches (rami communicantes grisei) which are a segment of postganglionic fibres stretching from the sympathetic trunk ganglia to a spinal nerve. As components of the grey communicating branches and the spinal nerves the postganglionic fibres spread in the vessels, glands, and smooth muscles of the skin of the trunk and limbs, as well as in the striated muscles for whose nutrition and tonus they are responsible.

Thus, the sympathetic nervous system is connected with the somatic system by two types of communicating branches, **grey and white**. The white communicating branches (medullated) are the preganglionic fibres.They stretch from the centres of the sympathetic nervous system through the anterior roots to the ganglia of the sympathetic trunk. Since the centres are situated at the level of the thoracic and upper lumbar segments, the white communicating branches are also present only in the area between the level of the first thoracic and that of the third lumbar spinal nerves. The grey communicating branches, the postganglionic fibres, provide for the vasomotor and trophic processes in the soma; they connect the sympathetic trunk with the spinal nerves for its entire length. The cervical part of the sympathetic trunk is also connected with the cranial nerves. All the plexuses of the somatic nervous system contain therefore fibres of the sympathetic system in their bundles and nerve trunks, which emphasizes the unity of these systems.

The sympathetic trunk

Each of the two sympathetic trunks is subdivided into fotir parts: cervical, thoracic, lumbar (or abdominal), and sacral (or pelvic).

The cervical part stretches from the base of the skull to the neck of the first rib; the sympathetic trunk lies behind the carotid arteries on the deep muscles of the neck. It has three cervical sympathetic ganglia: superior, middle, and inferior.

The superior cervical ganglion (ganglion cervicale superius) is the largest ganglion of the sympathetic trunk and is about 20 mm in length and 4-6 mm in breadth. It lies on the level of the second and partly the third cervical vertebrae behind the internal carotid artery and medial to the vagus nerve.

The middle cervical ganglion (ganglion cervicale medium) is small and is usually located at the intersection of the inferior thyroid artery with the carotid artery. Often it is absent or separated into two small ganglia.

The inferior cervical ganglion (ganglion cervicale inferius) is quite large and is situated behind the initial part of the vertebral artery; it is often fused with the first and sometimes also with the second thoracic ganglion to form a common inferior cervical ganglion (ganglion **cervicothoracicum** s. ganglion **stellatum**). Some authors describe four cervical ganglia of the sympathetic trunk which are linked with the development of the segmental arteries, namely, superior, middle, inferior, and stellate ganglia.

The cervical ganglia send nerves to the head, neck, and chest. These can be divided into an ascending group passing to the head, a descending group stretching to the heart, and a group running to the organs of the neck almost immediately from the site of origin.

The nerves for the head arise from the superior and inferior cervical ganglia and separate into a group of nerves that penetrate the cranial cavity and another group of nerves that reach the head from outer surface.

The first group is represented by **the internal carotid nerve** (n. caroticus internus) arising from the superior cervical ganglion, and the vertebral branch of the inferior cervical ganglion (n. vertebralis) branching off from the inferior cervical ganglion. Both nerves pass in attendance to arteries of the same names and form plexuses around them, namely **the internal carotid plexu**s (plexus caroticus internus) and **the vertebral plexus** (plexus vertebralis). Together with the arteries the nerves enter the cranial cavity where they anastomose with one another and send branches to the cerebral vessels, the meninges, the hypophysis, the trunks of the third, fourth, fifth, and sixth pairs of cranial nerves and to the tympanic nerve.

The internal carotid plexus (plexus caroticus internus) is continuous with **the cavernous plexus** (plexus cavernosus) which surrounds the internal carotid artery in the part passing through the cavernous sinus.

The branches of the plexus extend on the internal carotid artery itself and on its ramifications. Among the branches of the artery is **the deep petrosal nerve** (nervus petrosus profundus), which joins the greater superficial petrosal nerve (n. petrosus major) to form the nerve of **the pterygoid canal** (n. canalis pterygoidei) stretching through the pterygoid canal to the sphenopalatine ganglion (ganglion pterygopalatinum).

The second, external, group of the sympathetic nerves of the head consists of two branches of the superior cervical ganglion, **the external carotid nerves** (nervi carotici externi), which form plexuses around the external carotid artery and then pass in attendance to its ramifications on the head. The plexus sends a small ramus to the otic ganglion (ganglion oticum); **the facial plexus** (plexus facialis) gives off a branch accompanying the facial artery and passing to the submandibular ganglion.

Through rami included in the plexuses around the carotid artery and its branches, the superior cervical plexus sends fibres to the vessels (vasoconstrictors) and the glands of the head (sweat, lacrimal, mucous, and salivary), as well as to the smooth muscles of the hair and to the muscle which dilates the pupil, **m. dilatator pupillae.** The pupilodilator centre, called the ciliospinal centre (centrum ciliospinale), is in the spinal cord at the level between the seventh cervical and second thoracic segments.

The organs of the neck receive nerves from all three cervical ganglia; besides, some nerves arise from the intergangliont areas of the cervical part of the sympathetic trunk and still others from the plexuses of the carotid arteries.

The rami of the plexuses follow the course of the branches of the external carotid artery and are known by the same name; they approach the organs together with the arterial branches as a consequence of which the number of sympathetic plexuses is equal to the number of the arterial branches. Among the nerves arising from the cervical part of the sympathetic trunk mention should be made of **the pharyngeal branches** (rami laryngopharyngei) of the superior cervical ganglion, part of which pass with **the superior laryngeal nerve** (a branch of the vagus nerve) to the larynx and part descend to the lateral pharyngeal wall where together with the branches of the glossopharyngeal, vagus, and superior laryngeal nerves form **the pharyngeal plexus** (plexus pharyngeus).

The descending group of branches of the cervical sympathetic trunk segment is formed by **the cardiac branches** of the superior, middle, and inferior cervical ganglia **(nervi cardiaci cervicales superior, medius** and **inferio**r). They descend into the thoracic cavity and together with the cardiac branches of the sympathetic thoracic ganglia and branches of the vagus nerve contribute to the formation of the cardiac plexuses (see section dealing with innervation of the heart).

The thoracic part of the sympathetic trunk lies in front of the necks of the ribs and is covered anteriorly by pleura. It consists of 10 to 12 ganglia of a more or less triangular shape. The thoracic part is characterized by the presence of white communicating branches (rami communicantes albi) which connect the anterior roots of the spinal nerves with the sympathetic trunk ganglia. The branches of the thoracic part are as follows:

1) **the cardiac branches** (nervi cardiaci thoracici) arise from the superior thoracic ganglia and participate in the formation of the cardiac plexus (plexus cardiacus) (the cardiac plexuses are described in detail in the section dealing with the heart);

2) the grey communicating branches (rami communicantes grisei) which are non-medullated fibres supplied to the intercostal nerves (the somatic part of the sympathetic system);

3) **the pulmonary branches** (rami pulmonales) pass to the lungs to form the pulmonary plexus (plexus pulmonalis);

4) **the aortic branches** (rami aortici) form a thoracic **aortic plexus** (plexus aorticus thoracicus), partly on the oesophagus **- oesophageal plexu**s (plexus esophageus), and on the thoracic duct (the vagus nerve also contributes to the formation of these plexuses);

5) the greater and lesser splanchnic nerves (nervi splanchnici major and minor); **the greater splanchnic nerve** originates as several roots from the fifth to ninth thoracic ganglia, which then pass medially to the level of the ninth thoracic vertebra where they fuse into one common trunk which is transmitted through the space between the muscular bundles of t**he diaphragmatic crura** into the abdominal cavity in which it becomes a component of **the coeliac plexus** (plexus celiacus); **the lesser splanchnic nerve** arises from the tenth and eleventh thoracic ganglia, penetrates the diaphragm together with the greater splanchic nerve or is separated from it by a few muscular bundles, and also becomes a component of the coeliac plexus. Vasoconstricting fibres pass in the splanchnic nerves, which is confirmed by drastic overfilling of the intestinal vessels with blood when these nerves are divided; the splanchnic nerves also contain fibres inhibiting motor activity of the stomach and intestine and fibres conducting sensations from the viscera (the afferent fibres of the sympathetic system).

The lumbar, or abdominal part of the sympathetic trunk consists of four, sometimes of three, ganglia. Both sympathetic trunks come closer to each other in the lumbar part than in the thoracic part as a result of which the ganglia lie on the anterolateral surface of the lumbar vertebrae on the medial border of the psoas major muscle. **White communicating branches** are sent **only to the superior two or three lumbar nerves.**

Along its entire distance the abdominal part of the sympathetic trunk sends off a great number of branches which, together with the greater and lesser splanchnic nerves and the abdominal segments of the vagus nerves, form the largest unpaired **coeliac plexus** (plexus celiacus). Numerous spinal ganglia (C5-L3) also take part in its formation. The coeliac plexus lies on the anterior semicircumference of the abdominal aorta, behind the pancreas and surrounds the initial parts of **the coeliac trunk** (truncus celiacus) and **the superior mesenteric artery**. It occupies an area between the renal arteries, the suprarenal glands, and the aortic opening of the diaphragm and includes the paired ganglion of the coeliac artery - coeliac ganglion (ganglion celiacum), and sometimes the unpaired ganglion of the superior mesenteric artery - superior mesenteric ganglion (ganglion mesentericum superius) lying under the root of this artery.

The coeliac plexus also gives off some smaller paired plexuses to the diaphragm, suprarenals, and kidneys as well as **the testicular (ovarian) plexus** (plexus testicularis [ovaricus]) extending along the course of the arteries of the same name. There are also a series of unpaired plexuses which pass to some organs along the walls of arteries whose names they are given. Among these is the superior mesenteric plexus (plexus mesentericus superior) which supplies the pancreas, the small intestine and the large intestine to half the length of the transverse colon, and the ovary.

The second main source of innervation of the abdominal organs is the plexus on the aorta **- aortic plexus** (plexus aorticus abdominalis), formed by two trunks arising from the coeliac plexus and branches running from the lumbar ganglia of the sympathetic trunk. The aortic plexus gives rise **to the inferior mesenteric plexus** (plexus mesentericus inferior) for the transverse, descending, and sigmoid colon, and the upper part of the rectum (the superior rectal plexus, plexus rectalis superior). At the origin of the inferior mesenteric plexus lies **the inferior mesenteric ganglion** (ganglion mesentericum inferius) whose postganglionic fibres pass to the pelvis as components of the hypogastric nerves.

The aortic plexus is continuous with **the unpaired hypogastric plexus** (plexus hypogastricus superior) which bifurcates at the promontory of the sacrum (in two hypogastric nerves) and is in turn continuous with the pelvic plexus (**plexus hypogastricus inferior** s. plexus pelvinus). Fibres derived from the superior lumbar segments are functionally vasomotor (vasoconstrictor) in relation to the penis and motor in relation to the uterus and the sphinter urethrae muscle.

The sacral, or pelvic, part usually has four ganglia. Lying on the anterior surface of the sacrum along the medial margin of the anterior sacral foramen, both trunks gradually converge to terminate as one common unpaired ganglion impar on the anterior surface of the coccyx. The ganglia of the pelvic part, like those of the lumbar part, are connected both by small longitudinal and transverse trunks.

From the ganglia of the sacral part of the sympathetic trunk arise some branches which join the branches of the inferior mesenteric plexus to form a lamina stretching from the sacrum to the urinary bladder; this is the pelvic plexus (plexus hypogastricus inferior s. plexus pelvinus). It has its own small ganglia (ganglia pelvina). Several parts are distinguished in the pelvic plexus:

(1) **anteroinferior part** in which are distinguished a superior portion innervating the urinary bladder, **the vesical plexus** (plexus vesicalis) and an inferior portion supplying the prostatic gland, **the prostatic plexus** (plexus prostaticus), the seminal vesicles and ductus deferens, **the plexus of the vas deferens** (plexus deferentialis), and the cavernous bodies, cavernous nerves of the penis (**nervi cavernosi penis**);

(2) **posterior part** of the plexus supplies the rectum, the middle and inferior rectal plexuses (plexus rectales medii and inferiores). A third, middle part, is distinguished, in addition, in females; its inferior portion sends branches to the uterus and vagina, the uterovaginal plexus (**plexus uterovaginalis**) and the cavernous bodies of the clitoris, the cavernous nerves of the clitoris (**nervi cavernosi clitoridis**), while the superior portion gives off branches to the uterus and ovaries.

The parasympathetic nervous system

The parasympathetic system develops historically as a suprasegmental part and its centres are therefore located both in the spinal cord and in the brain.

The centres of the parasympathetic system

The central part of the parasympathetic system consists of **the cranial** and **the spinal, or sacral, part.** The parasympathetic centres are located in the spinal cord in the region of the sacral segments between the anterior and posterior horns, in the intermediate zone. The centres give rise to the efferent fibres of the posterior horns which cause dilation of the vessels and inhibition of perspiration and of the contraction of the smooth muscles of hairs on the trunk and limbs.

The cranial part

The cranial part consists, in turn, of centres lodged in **the midbrain** (mesencephalic part) and in the rhombencephalon, namely in the pons and medulla oblongata (**the bulbar part**).

1. The mesencephalic part is represented by **the accessory nucleus** (nucleus accessorius oculomotorii) **of the oculomotor nerve** (Edinger Wstphal, Yakubovich's nucleus) and by the median unpaired nucleus (Perlia) which are responsible for the innervation of the smooth muscles of the eye (m. sphincter pupillae and m. ciliaris).

2. The bulbar part is represented by **the superior salivary nucleus** (nucleus salivatorius superior) of the facial nerve (n. intermedius), **the inferior salivary nucleus** (nucleus salivatorius inferior) of the glossopharyngeal nerve, and **the dorsal nucleus** (nucleus dorsalis nervi vagi) of the vagus nerve.

The sacral part

The parasympathetic centres lie in the spinal cord, in the intermediolateral nucleus (nucleus intermediolateralis) of the lateral horn at the level of the second to fourth sacral segments (S2-S4).

The peripheral part of the parasympathetic system

The peripheral part of the cranial parasympathetic system consists of the following structures:

(1) preganglionic fibres passing in the third, seventh, ninth, and tenth pairs of cranial nerves (according to Mitchell, also in the first and eleventh pairs):

(2) terminal ganglia lying close to the organs (paraorganic ganglia), namely, the ciliary, pterygopalatine (sphenopalatine), submandibular, and otic ganglia, and intraorganic ganglia (intravisceral or intramural), located in submucosal layer of tubular organs and between muscular layer.

(3) postganglionic fibres which either stretch independently, e.g. the short ciliary nerves arising from the ciliary ganglion, or pass in some other nerves, e.g. postganglionic fibres originating from the otic ganglion and running in the auriculotemporal nerve. Certain authors claim that the parasympathetic fibres also emerge from different segments of the spinal cord through the dorsal roots and pass to the walls of the trunk and the limbs.

The peripheral part of the sacral parasympathetic system consists .of fibres which run in the anterior roots of the second, third, and fourth sacral nerves, then in their anterior branches forming **the sacral plexus** (somatic plexus) and finally enter the true pelvis. In the pelvis they leave the plexus and as t**he pelvic splanchnic** nerves (nn. splanchnici pelvini) pass **to the pelvic plexus** (plexus hypogastricus inferior) together with which they innervate the pelvic organs (the rectum with the sigmoid colon, the urinary bladder, and the external and internal genitalia). Stimulation of the pelvic splanchnic nerves causes contraction of the rectum and bladder (m. detrusor urinae) with relaxation of their sphincter muscles. The fibres of the sympathetic hypogastric plexus, in contrast, delay the evacuation of these organs; they stimulate uterine contractions, while the pelvic planchnic nerves inhibit it. The pelvic splanchnic nerves also contain vasodilator fibres (nn. erigentes) for the cavernous bodies of the penis and clitoris which are responsible for erection. The parasympathetic fibres arising from the sacral segment of the spinal cord extend to the pelvic plexuses not only in the erigentes and pelvic splanchnic nerves but also in the pudendal nerve (the preganglionic fibres). According to certain data, the pudendal nerve is a complex nerve containing, in addition to somatic fibres, vegetative (sympathetic and parasympathetic) fibres that form part of the inferior hypogastric plexus. The sympathetic fibres arising from the ganglia of the sacral segment of the sympathetic trunk as postganglionic fibres join the pudendal nerve in the true pelvis and pass through the inferior hypogastric plexus to the pelvic organs.

The intramural nervous system also belongs to the parasympathetic nervous system.

The walls of some hollow organs contain nerve plexuses of small ganglia (terminal) with ganglionic cells and non-medulated (amielinic) fibres; this is the gangliono-reticular, or intramural system.

The intramural system is particularly developed in the digestive tract (enteric nervous system) where it is represented by several plexuses.

1. The myenterie (Auerbach's) plexus (plexus myentericus Auerbachii) lies between the longitudinal and circular muscles of the digestive tube.

2. The submucous (Meissner's) plexus (plexus submueosus Meissneri) is located in the submucous tissue. It is continuous with the plexus of the glands and villi.

The plexuses receive nerve fibres from the sympathetic and parasympathetic systems. In the intramural plexuses the preganglionic fibres of the parasympathetic systems are switched over to the postganglionic fibres.

The vegetative innervation of organs

Innervation of the eye

Convergence and accommodation of the visual apparatus occur in response to definite visual stimuli arriving from the retina.

Convergence of the eyes, the bringing of their visual axes together to be fixed on the object examined, occurs by reflex due to associated contraction of the eyeball muscles. This reflex, necessary for binocular vision, is linked with accommodation of the eye. Accommodation, the property of the eye to see objects clearly at different distances from it, depends on contraction of the smooth muscles (the ciliary muscle and the sphincter of the pupil). In view of the fact that the activity of the smooth muscles of the eye occurs simultaneously with the contraction of its striated muscles, we shall discuss the vegetative innervation of the eye together with the somatic innervation of its motor apparatus.

The afferent pathway from the eyeball muscles (proprioceptive sensitivity) are, according to some authors, the somatic nerves innervating these muscles (the third, fourth, and sixth cranial nerves) and according to others, the ophthalmic nerve (the first division of the trigeminal nerve).

The centres of innervation of the eyeball muscles are the nuclei of the third, fourth, and sixth pairs. The efferent pathway are the third, fourth, and sixth cranial nerves. Convergence of the eye, as it is pointed out above, is accomplished by simultaneous contraction of the muscles of both eyes.

It should be borne in mind that isolated movement of one eyeball does not occur altogether. Both eyes always take part in any voluntary and reflex movements. Associated movement of the eyeballs (the gaze) is produced by a special system of fibres connecting the nuclei of the third, fourth, and sixth nerves to one another; it is called the medial longitudinal bundle.

The medial longitudinal bundle arises in the cerebral peduncle from Darkshevich's nucleus. It is connected to the nuclei of the third, fourth, and sixth nerves by means of collaterals and descends on the brain stem into the spinal cord where it evidently terminates in the cells of the anterior horns of the superior cervical segments. Due to this, the movements of the eyes are combined with movements of the head and neck.

The smooth muscles of the eyes, i.e. the ciliary muscle and the sphincter of the pupil, responsible for accommodation, are supplied with parasympathetic innervation; the dilator of the pupil receives nerves from the sympathetic system. The oculomotor and ophthalmic nerves are the afferent pathways of the vegetative system.

Efferent parasympathetic innervation. The preganglionic fibres pass from Yakubovich's nucleus (mesencephalic part of the parasympathetic nervous system) in the oculomotor nerve and in the root of this nerve reach the ciliary ganglion in which they terminate. The ciliary ganglion gives rise to the postganglionic fibres which through the short ciliary nerves (nn. ciliares breves) reach the ciliary muscle and the circular muscle of the iris (sphincter of the pupil). **Function**: contraction of the pupil and accommodation of the eye to vision at a long and short distance.

Efferent sympathetic innervation. The preganglionic fibres arise from the cells of the intermediolateral nucleus, the lateral horns of the last cervical and two upper thoracic segments (C8— Th2, centrum ciliospinale), emerge through two superior thoracic white communicating branches, pass in the cervical segment of the sympathetic trunk, and terminate in the superior cervical ganglion. The postganglionic fibres pass in the internal carotid nerve into the cranial cavity and enter the internal carotid and ophthalmic plexuses; after that some of the fibres penetrate into the communicating branch which is connected with the nasociliary and the long ciliary nerves, while others pass to the ciliary ganglion through which they extend without interruption into the short ciliary nerves. The sympathetic fibres passing in the long ciliary nerves, as well as those passing in the short ciliary nerves, reach the radial muscle of the iris (the dilator of the pupil). **Function**: dilation of the pupil and constriction of the eye vessels.

Innervation of the lacrimal and salivary glands

The afferent pathway for the lacrimal gland are the lacrimal nerve (a branch of the ophthalmic nerve which is the first division of the trigeminal nerve), for the submandibular and sublingual glands the lingual nerve (a branch of the mandibular nerve which is the third division of the trigeminal nerve), and the chorda tympani (a branch of nervus intermedius, formerly called the sensory root of the facial nerve). The auriculotemporal and glossopharyngeal nerves are the afferent pathways for the parotid gland.

Efferent parasympathetic innervation of the lacrimal gland. The centre is in the upper part of the medulla oblongata and is connected with the nucleus of the nervus intermedius (the superior salivary nucleus). The preganglionic fibres extend as components of nervus intermedius and then of greater superficial petrosal nerve to the sphenopalatine ganglion. This ganglion gives rise to the postganglionic fibres which as components of the maxillary nerve and then of its branch, the zygomatic nerve, reach the lacrimal gland through connections with the lacrimal nerve.

Efferent parasympathetic innervation of the submandibular and sublingual glands. The preganglionic fibres extend from the superior salivary nucleus as components of nervus intermedius, then of the chorda tympani and the lingual nerve to the submandibular gang lion from which the postganglionic fibres arise and reach the glands in the lingual nerve. Efferent parasympathetic innervation of the parotid gland. The preganglionic fibres pass from the inferior salivary nucleus as components of the glossopharyngeal nerve, then of the tympanic and the lesser superficial petrosal nerve to the otic ganglion. Here arise the postganglionic fibres and extend in the auriculotemporal nerve to reach the gland. **Function**: stimulation of the secretion of the lacrimal and the salivary glands mentioned above; dilation of the vessels of the glands.

Efferent sympathetic innervation of all the glands named above. The preganglionic fibres originate in the lateral horns of the superior thoracic segments of the spinal cord and terminate in the superior cervical ganglion. The postganglionic fibres arise in this ganglion and reach the lacrimal glands as components of the internal carotid plexus, the parotid gland in the external carotid plexus, and the submandibular and sublingual glands through the external carotid plexus and then through the facial plexus. **Function**: inhibition of saliva secretion (dryness in the mouth); mild stimulation of lacrimation.

Innervation of the heart

The afferent pathways extend from the heart in the vagus nerve and in the cardiac branches of the middle and inferior cervical and the thoracic sympathetic ganglia. **The sense of pain** is conducted along the sympathetic nerves, all the other afferent impulses along the parasympathetic nerves.

Efferent parasympathetic innervation. The preganglionic fibres arise in the dorsal vegetative nucleus of the vagus nerve and pass in it and in its cardiac branches and cardiac plexuses to the ganglia located in the heart , and to the ganglia of the pericardial fields. Postganglionic fibres arising from these ganglia extend to the heart muscle. **Function**: inhibition and suppression of cardiac activity. Constriction of the coronary arteries.

Efferent sympathetic innervation. The preganglionic fibres originate in the lateral horns of the spinal cord of the upper four or five thoracic segments, pass in the corresponding white communicating branches and then through the sympathetic trunk to the five upper thoracic and three cervical ganglia. These ganglia give rise to the postganglionic fibres which as components of the cardiac branches of the superior, middle, and inferior cervical and the thoracic ganglia reach the heart muscle. According to certain authors, the pathway is interrupted only in the stellate ganglion. The cardiac branches of the ganglia contain preganglionic fibres which switch over to postganglionic fibres in the cells of the cardiac plexus. **Function**: (1) stimulation of cardiac activity (a fact established by Pavlov in 1888 who called the sympathetic nerve the "stimulating" nerve), (2) increase of the heart beat rate (determined by Tsion in 1866), and (3) dilation of the coronary vessels.

Innervation of the lungs and bronchi

The afferent outflow from the visceral pleura occurs along the pulmonary branches of the thoracic sympathetic trunk, from the parietal pleura along the intercostal and phrenic nerves, and from the bronchi along the vagus nerve.

Efferent parasympathetic innervation. The preganglionic fibres originate in the dorsal vegetative nucleus of the vagus nerve and extend as components of this nerve and its pulmonary branches to the ganglia of the pulmonary plexus and to ganglia arranged along the course of the trachea and bronchi and in the lungs. The postganglionic fibres stretch from these ganglia to the muscles and glands of the bronchial tree. Function: constriction of bronchi and bronchioles, stimulation of mucus excretion, dilation of vessels.

Efferent sympathetic innervation. The preganglionic fibres emerge from the lateral horns of the spinal cord of the superior thoracic segments (Th2— Th3) and pass through the corresponding white communicating branches and the sympathetic trunk to reach the stellate or upper thoracic ganglia. From the last named originate the postganglionic fibres which reach the bronchial muscles and blood vessels as components of the pulmonary plexus. **Function**: dilation of bronchi, constriction and sometimes dilation of vessels.

Innervation of the gastrointestinal tract, pancreas and liver

The afferent outflow from these organs occurs along fibres which are constituents of the vagus and the lesser and greater splanchnic nerves, the hepatic and coeliac plexuses, and the thoracic and lumbar spinal nerves, and, according to some authors, also of the phrenic nerve.

The sympathetic nerves conduct the sense of pain from these organs; the vagus nerve conducts the other afferent impulses as well as the sense of nausea and hunger from the stomach.

Efferent parasympathetic innervation. Preganglionic fibres from the dorsal vegetative nucleus of the vagus nerve pass as components of the last named to the terminal ganglia in the tissues of the organs discussed. In the intestine these are the cells of the intestinal plexuses (the niyenteric and submucous plexuses). From the ganglia the postganglionic fibres run to the smooth muscles and glands. **Function**: stimulation of peristalsis of the stomach, relaxation of the pyloric sphincter, stimulation of peristalsis of the intestine and gall bladder. The vagus nerve contains fibres which stimulate and inhibit secretion. Efferent parasympathetic innervation is also concerned with dilation of vessels.

Efferent sympathetic innervation. The preganglionic fibres emerge from the lateral horns of the fifth to twelfth spinal segments and then pass in the corresponding white communicating branches into the sympathetic trunk and then without interruption, as components of the greater splanchnic nerves (between the sixth and ninth ganglia), reach the intermediate ganglia contributing to the formation of the coeliac and mesenteric plexuses. Here arise the postganglionic fibres which as components of the coeliac and superior mesenteric plexuses extend to the liver, pancreas, the small and large intestine and to the level of the middle of the transverse colon; the left half of the transverse colon and the descending colon are innervated by the inferior mesenteric plexus. The plexuses mentioned supply the muscles and glands of the organs discussed. Function: inhibition of gastric, intestinal and gall bladder peristalsis, constriction of the blood vessels, and inhibition of glandular secretion.

It should be added that the movement of the gastric and intestinal contents can also be delayed because the sympathetic nerves cause active contraction of the pyloric, intestinal, and other sphincters.

Innervation of the sigmoid colon, rectum, and urinary bladder

The afferent pathways run as components in the inferior mesenteric, superior and inferior hypogastric plexuses, and in the pelvic splanchnic nerves.

Efferent parasympathetic innervation. The preganglionic fibres arise in the lateral horns of the second to fourth sacral spinal segments and emerge as components of the corresponding anterior roots of the spinal nerves. They then pass as the pelvic splanchnic nerves to the intraorganic ganglia of the parts of the large intestine discussed and to the ganglia located around the urinary bladder. All these ganglia give rise to the postganglionic fibres which reach the smooth muscles of the organs. Function: stimulation of peristalsis of the sigmoid colon and rectum, relaxation of the sphincter and internus muscle, contraction of the detrusor urinae, and relaxation of the sphincter vesical muscle.

Efferent sympathetic innervation. The preganglionic fibres pass from the lateral horns of the lumbar spinal cord through the corresponding anterior roots into the white communicating branches, run without interruption through the sympathetic trunk, and reach the inferior mesenteric ganglion. In this ganglion arise the postganghonic fibres which then extend as components of the hypogastric nerves to the smooth muscles of the organs discussed. Function: inhibition of peristalsis of the sigmoid colon and rectum and contraction of the sphincter and internus muscle. The sympathetic nerves in the urinary bladder cause relaxation of the detrusor urinae and contraction of the sphincter urethrae muscle.

Innervation and blood supply of the of the urinary system

The kidney

At the renal hilum, **the renal artery** separates into arteries according to the parts of the kidney, namely vessels for the upper pole, **the superior polar arteries**, for the lower pole, **inferior polar arteries**, and for the middle part of the kidney, **the central arteries**. In the kidney parenchyma, these arteries pass between the pyramids, i.e. between the lobes of the kidney, and are, therefore, called **the interlobar arteries** (aa. interlobares renis). At the base of the pyramid at the junction of the medulla and cortex, they form arterial arches, **the arciform arteries** (aa. arcuatae), which give rise to **the interlobular arteries** (aa. interlobulares) piercing the cortex. Each interlobular artery gives origin to **vas afferens**, which ramifies to form a tuft of **convoluted capillaries**, the glomerulus, invaginated in the initial part of the renal tubule, **the Bowman capsule**. **The vas efferens** emerging from the glomerulus again breaks up into capillaries, which first surround the renal tubules and only after that they are continuous with the veins. **The veins** accompany the corresponding arteries and leave the renal hilum as a common trunk, the renal vein (vena renalis) draining into the vena cava inferior. Venous blood drains from the cortex first into **the stellate veins** (venulae stellatae), then into the interlobular veins accompanying the interlobular arteries, and then into the arcuate veins. Venous blood from the medulla flows in the venulae rectae. The large venous tributaries unite to form the renal vein. In the region of the renal sinus, the veins are in front of the arteries.

The kidney, therefore, contains **two capillary systems**: one connects the arteries with the veins while the other is of a special character comprising a vascular tuft, in which blood is isolated from the capsular cavity by only two layers of squamous cells (the endothelium of the capillaries and the endothelium of the capsule). This provides favourable conditions for the excretion of water and metabolites from blood.

The lymphatic vessels of the kidney are divided into superficial vessels arising from the capillary networks of the renal capsules and from the peritoneum covering the kidney, and deep vessels passing between the lobules. There are no lymphatics within the lobules or in the glomeruli.

Both vascular systems merge for the most part at the renal sinus, then pass in attendance to the renal blood vessels to the regional lymph nodes, but to different nodes from each kidney: vessels from the right kidney drain into nodes around the vena cava inferior (the pre- and retrocaval nodes), into nodes situated between the vena cava inferior and the aorta (interaortacaval nodes), and into nodes lying in front of the aorta (preaortic nodes); lymphatic vessels from the left kidney drain into nodes situated to the left of the aorta (left latero-aortic nodes) and in front of it (pre-aortic nodes).

The nerves of the kidney are derived from the paired renal plexus formed by the splanchnic nerves, branches of the sympathetic ganglia, branches of the solar plexus with fibres of the vagus nerves contained in them, and the afferent fibres of the inferior thoracic and superior lumbar spinal ganglia.

The ureter receives blood from several sources. The renal **artery supplies** branches to the walls of the renal pelvis and upper part of the ureter. Branches to the ureter are also given off by the testicular artery (or the ovarian artery) at their intersection. The middle part of the ureter is supplied with ureteral branches from the aorta, common iliac artery or internal iliac artery. The pelvic part is supplied with nutrients from the middle rectal artery and the inferior vesical arteries. **Venous blood** drains into the testicular (or ovarian) and internal iliac veins. **Lymph** is drained into the abdomino-aortic (lumbar) and iliac lymph nodes. **The nerves** of the ureter are of sympathetic origin: they run to the upper part from the renal plexus, to the lower portion of the abdominal part from the ureteric plexus, and to the pelvic part from the inferior hypogastric plexus. In addition, the ureters are supplied with parasympathetic innervation from the pelvic splanchnic nerves.

The bladder

Vessels and nerves: the walls of the bladder receive blood from the inferior vesical artery, which is a branch of the internal iliac artery, and from the superior vesical artery, which is a branch of the umbilical artery. The middle rectal artery and other neighbouring arteries also contribute to vascularization of the bladder. **The veins** of the bladder drain partly into the vesical venous plexus and partly into the internal iliac vein. **Lymph** flows into the internal iliac lymph nodes. The bladder is **innervated** from the inferior vesical plexus, which contains sympathetic nerves from the hypogastric plexus and parasympathetic nerves from the pelvic splanchnic nerves.

Innervation and blood supply of the of the reproductive organs

The male genital organs

The testis. Arterial blood is supplied to the testis and epididymis by the testicular artery, the artery of the ductus deferens, and partly by the cremasteric artery. **Venous** blood drains from the testis and epididymis into the pampiniform plexus and then into the testicular vein. **The lymphatic vessels** from the testis pass as components of the spermatic cord and, by-passing the inguinal nodes, terminate in the lumbar lymph nodes. This, as well as the high position of the testicular artery and veins, is associated with the fact that the testis is laid down in the lumbar region. **The nerves** of the testis form the sympathetic testicular and deferential plexuses around the testicular and deferential arteries.

The ductus deferens receives arterial blood from the artery of the vas deferens (branch of the internal iliac artery).

The seminal vesicles are supplied from the inferior vesical, vas deferens, and rectal arteries. **Venous** blood flows into the vena deferentialis draining into the internal iliac vein. **Lymph** flows into the internal iliac lymph nodes. The ductus deferens and seminal vesicles are **innervated** from the plexus of the vas deferens formed by nerves from the pelvic plexus.

The penis. **The arteries** of the penis are branches of the femoral artery (the external pudendal arteries) and the internal pudendal artery. **Venous blood** is drained by the superficial and deep dorsal veins of the penis into the femoral vein and the vesical venous plexus. **Lymph** flows into the inguinal lymph nodes and the nodes of the true pelvis. Afferent **innervation** is derived from the pudendal nerve, efferent sympathetic innervation from the inferior hypogastric plexus, and efferent parasympathetic innervation from the erigentes nerves.

The urethra. **The arteries** of the urethra originate from the branches of the internal pudendal artery. The different parts of the canal are supplied from different sources: the prostatic part, from branches of **the middle rectal** and **inferior vesical arteries**; the membranous part from **the inferior rectal and perineal arteries**; the spongy part from the internal pudendal artery. **The dorsal and deep arteries** of the penis also contribute to the vascularization of the urethral walls. **Venous blood** flows into the veins of the penis and those of the urinary bladder. **Lymph** from the prostatic part drains into the prostatic lymphatic veins, lymph from the membranous and spongy parts into the inguinal nodes. **Innervation** is accomplished from the perineal nerves and the dorsal nerve of the penis (from the pudendal nerve) and from the vegetative prostatic plexus.

Arteries reach **the bulbourethral glands** from the internal pudendal artery. Venous blood flows into the veins of the bulbus and urogenital diaphragm. The lymphatic vessels drain into the internal iliac lymph nodes. The glands are innervated from the pudendal nerve.

The prostate is supplied with **arterial blood** from the inferior vesical and median rectal arteries. **Veins** enter the vesical and prostatic plexus draining into the inferior vesical veins; the vessels of the prostate develop fully only with the onset of puberty. **The lymphatic** vessels drain into nodes situated in the anterior parts of the pelvic cavity. **The nerves** are derived from the inferior hypogastric plexus.

The female genital organs

The ovary is supplied with nutrients from **the ovarian artery** and ovarian branches of the uterine artery. The ovarian veins correspond to the arteries; they arise from the pampiniform (vine-shaped) plexus, pass through the suspensory ligament of the ovary, and drain into the vena cava inferior (right) and left renal vein (left). The lymphatic vessels drain lymph into the aortic lymph nodes. **Innervation**: the ovary is supplied with sympathetic (from the coeliac, superior mesenteric, and inferior hypogastric plexus) and parasympathetic innervation. Some authors question the existence of the parasympathetic innervation, but it cannot be flatly denied.

The uterus receives arterial blood from **the uterine artery** and partly from the **ovarian artery**. The uterine artery supplying the uterus, the broad and round ligaments, the tube, the ovary, and the vagina passes in the base of the broad ligament downward and medially, crosses the ureter, gives off **the vaginal artery** to the cervix and vagina, and then turns upward and ascends to the upper uterine angle. The uterine artery lies on the lateral border of the uterus and in females who have borne children is distinguished by its **tortuousness**. On its way it gives off branches to the body of the uterus. On reaching the fundus, the uterine artery separates into two terminal branches, **ramus tubarius** (to the tube) and **ramus ovaricus** (to the ovary). The branches anastomose in the uterine tissue with the collateral branches and form rich networks in the muscular and mucous coats and develop particularly in pregnancy. The uterus is drained of **blood by veins** which form the uterine plexus. From this plexus the blood flows in three directions: (1) from the ovary, tube, and upper part of the uterus into the ovarian vein; (2) from the lower half of the uterine body and upper portion of the neck into the uterine vein; (3) from the lower portion of the neck and the vagina directly into the internal iliac vein. The uterine plexus anastomoses with the veins of the bladder and the rectal plexus. **The lymphatic vessels** draining the uterus pass in two directions: (1) from the uterine fundus along the tubes to the ovaries and then to the aortico-abdominal (lumbar) nodes; (2) from the body and neck of the uterus in the sacral nodes

The vagina

The vessels and nerves of the vagina are related intimately to those of the uterus. **The-arteries** of the vagina arise from the uterine artery and partly from the inferior vesical, the middle rectal, and the internal pudendal arteries. **The veins** form on the sides of the vagina rich venous plexuses, which anastomose with the veins of the external genital organs and the venous plexuses of the neighbouring pelvic organs. Blood from the plexus flows into the internal iliac vein. The vagina is drained of **lymph** in three directions: from the upper part to the internal iliac nodes, from the lower part to the inguinal nodes, and from the posterior wall to the sacral nodes. **The nerves** of the vagina are derived from the inferior hypogastric plexus (sympathetic nerves), the pelvic splanchnic nerves (parasympathetic nerves), and the pudendal, nerve (to the lower part of the vagina).

The pudendum receives **arterial** blood from the internal and external pudendal arteries. **Venous** blood drains into the internal and external pudendal veins and into the inferior rectal vein. **Lymph** flows into the superficial inguinal nodes. **Innervation** is supplied from the ilioinguinal, genitofemoral, and pudendal nerves and from the sympathetic trunk.

The female urethra receives **arteries** from the inferior vesical and internal pudendal arteries. **The veins** drain by way of the vesical venous plexus into the internal iliac vein. **Lymphatic** vessels from the upper parts of the urethra pass to the iliac lymph nodes, those from the lower parts to the inguinal lymph nodes. **Innervation** is supplied from the inferior hypogastric plexus, and the pelvic splanchnic and pudendal nerves.

Innervation and blood supply of the endocine glands

The thyroid receives **two superior thyroid arteries** (from the external carotid artery), **two inferior thyroid arteries** (from the thyrocervical trunk arising from the subclavian artery) and **a fifth unpaired** (inconstant) artery**, a. ima**, which can arise from the brachiocephalic trunk, the subclavian artery or even from the arch of the aorta. **The veins** form plexuses, which lie under the external capsule; these plexuses drain into three veins on either side: **the superior, middle, and inferior thyroid veins** (the first two drain into the internal jugular vein, while the inferior vein drains into the left brachiocephalic vein). **The lymphatic vessels** are numerous and form a rich plexus; they conduct the colloid, pass in attendance to the arteries and drain into the tracheal, deep cervical, and mediastinal lymph nodes. **The nerves** arise from the sympathetic trunk (mainly from the middle cervical ganglion and partly from the superior and inferior ganglia), from the vagus nerve (by way of the superior and inferior laryngeal nerves) and, possibly, from the glossopharyngeal nerve.

The parathyroids are supplied with **arterial** blood from branches of the inferior and superior thyroid arteries and in some cases from branches of the oesophageal and tracheal arteries. Wide sinusoid capillaries are inserted between the arteries and veins. The sources of **innervation** are the same as in the thyroid gland, the nerve branches are numerous.

The hypophysis

A specific feature of the **blood supply** to the hypophysis is the existence of **a portal system in its anterior lobe**: numerous (10-25) small branches of the circle of Willis soon ramify in the hypophysial stalk into capillaries, which drain into **the portal veins** entering the hypophysial hilus and again ramifying into capillaries, sinusoids, in the tissue of the-gland. These give rise to the veins draining the hypophysis. The posterior lobe receives branches from the internal carotid artery. Both lobes are supplied separately with arterial blood but their vessels anastomose with one another.

The arterial anastomoses and the joining of the capillary bed of the two parts of the hypophysis can be regarded as potential collateral channels of the blood supply to the organ. They provide the possibility for the redistribution of blood in changed intensity of hypophysial activity as well as during neuro-numoral correlations of the functionally different components of this organ. **Venous** blood drains into plexus situated at the base of the brain and then into the cerebri magna vein. **The lymphatic** vessels drain into the subarachnoid space, into which some hormones enter. **The nerves** (sympathetic) arrive from, the pia mater plexus.

The pineal body receives some branches from the posterior choroid artery (a branch of the posterior cerebral artery), and the superior cerebellar and middle cerebral arteries. The sympathetic fibres entering the pineal body are evidently intended for innervation of the blood vessels.

The adrenals (suprarenal glands) receive three pairs of **arterial** branches: superior suprarenal arteries (from the inferior phrenic artery), middle (from the abdominal aorta), and inferior suprarenal arteries (from the renal artery). They all anastomose with one another to form a network in the capsule of the glands. **Venous** blood passes through the wide venous capillaries (sinusoids) and usually drains along a single vessel, the suprarenal (central) vein, which leaves the gland through the hilum and drains into the vena cava inferior (the right vessel) and into the left renal vein (the left, longer vessel). The **lymphatic** vessels run to the lymph nodes situated at the aorta and vena cava inferior.

The nerves pass from the major splanchnic nerve (through the coeliac and renal plexus).

Innervation of the blood vessels

The extent of innervation of the arteries, capillaries, and veins differs. Arteries with well developed muscular elements in the tunica media are supplied with nerves most richly, the veins are supplied less richly; the inferior vena cava and the portal vein occupy an intermediate position.

The larger vessels situated in the body cavities receive innervation from branches of the sympathetic trunk, the nearest plexuses of the vegetative system, and the adjoining spinal nerves; the peripheral vessels of the cavitary walls and the vessels of the limbs are supplied by nerves passing close to them. Nerves approaching the vessels run segmentally and form perivascular plexuses which give off branches; after penetrating the wall these branches are distributed in the adventitia (tunica externa) and between it and tunica media. The fibres supply the muscular structures of the wall for which purpose their terminations are shaped differently. It has been proved to date that receptors are present in all arteries, veins, and lymphatic vessels.

The first neuron of the afferent outflow from the vascular system is in the intervertebral ganglia or in the ganglia of the vegetative nerves (the splanchnic and the vagus nerves); it then passes as a component of the conductor of the interoceptive analyser. The vasomotor centre is in the medulla oblongata. The globus pallidus, thalamus, and tuber cinereum are concerned with the regulation of circulation. The higher centres of circulation, like the centres of all vegetative functions, are located in the cortex of the cerebral motor zone (the frontal lobe) and in front and to the back of it. According to the certain data, the cortical centre of the vascular function analyser is evidently found in all parts of the cortex. The efferent connections of the brain with the stem and spinal centres are evidently effected by the pyramidal and extrapyramidal tracts.

Closure of the reflex arc may occur at all levels of the central nervous system. Some authors believe that it may also be accomplished in the peripheral part of the nervous system through Dogiel's cells of the second type located in the ganglia of the vegetative plexuses (the vegetative reflex arc proper).

The efferent path causes a vasomotor effect, i.e. dilation or constriction of the vessels. The vasoconstricting fibres pass in the sympathetic nerves, the vasodilating fibres run in all parasympathetic nerves of the cranial part of the vegetative system (third, seventh, ninth, and tenth pairs), in the posterior roots of the spinal nerves (not all authors share this viewpoint), and in the parasympathetic nerves of the sacral part (the splanchnic pelvic nerves).

There is disagreement concerning efferent innervation of the capillaries. Some authors claim that capillaries, being devoid of muscular elements, are also devoid of the corresponding efferent innervation; others have described nerve endings on capillaries located in the brain parenchyma (axovasal connections).

Unity of the vegetative and somatic (animal) parts of the nervous system

It must be borne in mind that the vegetative system is a part of an integral nervous system. That is why combined activity of the vegetative and somatic parts of the nervous system with involvement of centres situated in different levels of the nervous system is continuously encountered in the whole organism.

We shall examine here such a combined activity, taking as an illustration the regulation of the act of micturition.

The urinary bladder, like any other organ, functions according to the law of the reflex: with the gradual accumulation of urine in the bladder, it becomes distended which causes stimulation of the interoceptors; the stimulation is conducted along the sensory fibres of the pelvic nerves (the splanchnic pelvic nerves) and the posterior sacral roots to the second, third, and fourth sacral segments. On entering the spinal cord, some of the impulses pass to the spinal centre of the urinary bladder, the nucleus of the splanchnic pelvic nerves. From this nucleus the motor impulses are conducted along the parasympathetic fibres of the splanchnic pelvic nerves (extending as components of the hypogastric plexus) to the smooth muscle, the detrusor urinae (ejector of urine) situated in the wall of the bladder. The strong contraction of the detrusor is accompanied by relaxation of the sphincter vesicae muscle (which is usually contracted) and micturition occurs. The sphincter vesicae muscle and the detrusor are innervated also by sympathetic fibres which emerge from the superior lumbar spinal segments, pass through the ganglia of the sympathetic trunk, and terminate in the inferior mesenteric ganglion. After interruption in the ganglion, the postganglionic fibres enter the inferior hypo-gastric plexus and then pass into the sphincter vesicae and the detrusor urinae muscles and, in contrast to the parasympathetic fibres, relax the detrusor and cause contraction of the sphincter which prevents urination.

The act of micturition, however, may not take place even when the urinary bladder is distended (and the interoceptors stimulated) and there is the urge to urinate. This happens because the other part of the impulses pass along the ascending conduction pathways to the diencephalic parts of the brain associated with instinctive activity and into the cortical analyser (to the paracentral lobule) in which the spinal and instinctive micturition mechanisms are brought into coordination with the need of the given moment, i.e. the passing of urine is either inhibited or stimulated following the urge to urinate. Due to this cortical centre, the passage of urine can be suppressed for a certain time despite the urge to urinate. This is accomplished by the striated sphinter urethrae muscle which is innervated by the pudendal nerve emerging from the second, third, and fourth spinal segments.

Voluntary innervation of the bladder connects each paracentral lobule with both halves of the spinal cord, i.e. both nuclei of the splanchnic pelvic nerves. As a result, a lesion of one cerebral hemisphere or one half of the spinal cord does not lead to disorders of micturition.

Zakharyin-head's areas or zones.

Zakharyin-Head's areas or zones Information about afferent innervation of the viscera by the animal nervous system is now availabl. This possibly explains the long known symptom of referred pain encountered in the clinic. Diseases of some internal organs are always attended by pain referred to definite skin areas. Such, for instance, is pain felt in the left shoulder blade and left arm in angina pectoris, pain between the shoulder blades in gastric ulcer, pain in the right iliac fossa in appendicitis, etc. Such pain is localized in definite skin areas corresponding to the segments of the spinal cord which receive afferent (sensory) fibres from the diseased internal organ. Such skin areas, or zones, are called the **Zakharyin Head's zones** after the authors who described them. Knowledge of Zakharyin-Head's zones helps to judge the condition of organs of the internal cavities according to pain experienced in the skin areas. These zones are possibly responsible for the effect produced by cauterization or puncturing with needles (needle therapy, acupuncture) of certain points on the skin, i.e. treatment applied in Chinese medicine.

According to certain data, the intraorganic nerves of parenchymatous organs are distributed, like the vessels, according to the segments of the organs. In the right lung, for instance, 10 or 11 neural segments are distinguished and in the left lung nine or ten. The number of neural segments in the liver varies greatly and may be up to eight. Five innervation segments are encountered in the kidney.

AESTHESIOLOGY
(THE SENSRY ORGANS)

General data

The sensory organs (organs sensuum) or analysers, are instruments by means of which the nervous system receives stimuli from the environment as well as from the organs of the body itself and perceives these stimuli in the form of sensations. The indication of our sensory organs serve as the source of our realization of the world surrounding us. If it were not for our sensation we would be incapable of learning about any forms of matter or any forms of movement. This is why V. I. Lenin regarded the physiology of the sensory organs as one of the sciences forming the basis for building the dialectical materialistic theory of knowledge.

The process of sensory cognition in man is accomplished by five senses, namely by touching, hearing, seeing, tasting and smelling. The five senses provide man with a wide variety of information about the objective world surrounding us, which is reflected in our consciousness in the form of subjective images by feeling, perceiving and remembering.

Live protoplasm can be stimulated and is capable of responding to stimulation. In the process of phylogenesis this ability is particularly developed in specialized cells of the skin epithelium under the effect of external stimuli and in cells of intestinal epithelium under the effect of stimulation by food. The specialized cells of the epithelium have been associated with the nervous system as early as the coelenteratae stage. In some parts of the body, in the feelers, for instance, in the region of the mouth the specialized cells possessing heightened excitability form accumulations from which the simplest sensory organs originate. Later, depending on the position of these cells, their specialization is accomplished in relation to stimuli. Thus, the cells in the region of the mouth become specialized in the appreciation of chemical stimuli (smell, taste) and the cells in the protruding parts of the body specializes in the appreciation of mechanical stimuli (perceptible by touch), and so on.

The development of the sensory organs depends on the importance of their adaptation to conditions of existence. For example, the dog has a fine sense of smell and can distinguish negligible concentrations of organic acids secreted by the body of animals (hence the ability to trace footsteps) but cannot make out the odours of plants which are of no biological significance for the dog.

The increased fineness achieved in the analysis of the outer world is the result not only of more complicated structure and function of the sensory organs, but mainly of a more complex nervous system. The development of the brain (particularly of its cortex) acquires a very special significance for analysing the environment; because of this was called the sensory organs "tools of the brain". We perceive the nerve excitation arising from this or that stimulus in the form of different sensations. The theory of reflection maintains that sensation is the reflection in our consciousness of objects and phenomena of the environment as a result of their effect on our sensory organs. When light affects the retina of the eye, for example, it arouses nerve impulses which produce visual sensations in our consciousness as they are conveyed along the nervous system.

Sensations will arise if there are devices appreciating the stimuli, nerves along which the stimulus is conveyed, and the brain where it is transformed into a factor of consciousness. All this apparatus necessary for the sensation to occur was called the "analyser". The analyser is an instrument which decomposes the complexity of the environment into its separate elements.

Every analyser consists of three parts: **(1) the receptor** which transforms the energy of the stimulus into a nerve process; **(2) the conductor** which conveys the nerve excitation; **(3) the cortical end** of the analyser where the excitation is perceived as a sensation.

There are two groups of sensations.

1. Sensations reflecting the properties of objects and phenomena of the material, world around us: the sensation of touch and pressure, the sensation of temperature (heat and cold), the sensation of pain; and also the sensations of hearing, sight, taste and smell.

2. Sensations reflecting the movement of different parts of the body and the condition of the internal organs (motor sensations, the sense of body balance, the sensations of organs and tissues).

In accordance, all organs are divided into two groups.

1. Organs of external sensibility which receive nerve impulses from the exteroceptive field, the exteroceptors. There are five such sensory organs: those of cutaneous sense, hearing, sight, taste and smell.

2. Organs of inner sensibility: (a) those which receive impulses from the proprioceptive field (the muscle-joint sensation), as well as from the organ of balance (the internal ear); they are termed the proprioceptors: (b) organs receiving nerve impulses from the interoceptive field (internal organs and vessels), these are the interoceptors.

The sensations coming from the internal organs are usually indefinite in the normal state of these organs, do not reach the consciousness, and are only reflected in a person's impression of his "general condition". Actually all the internal processes regulated by the vegetative nervous system take place irrespective of our will and become manifested only during morbid disorders by more or less severe pain. As to excitations coming from the proprioceptive field, mention must be made only of the muscle-joint sensation, which makes a person aware of the position of the parts of his body and which is important for the coordination of movements. On the one hand, this sensation is combined with cutaneous sensitivity (the property of stereognosis), and on the other, it is connected with the statokinetic apparatus, which is responsible for the equilibrium of the body. The nerve endings (in the muscles, bones, tendons and joints) and the conductors of the muscle-joint sensation were described when we discussed the motor analyser. This is why the organ of equilibrium is the only proprioceptor described here. In this section we shall therefore describe only organs appreciating sensations from the environment, i.e. the exteroceptors.

The general plan of receptive devices in all classes of animals is more or less the same despite subsequent .considerable complication of details. The basic element, with the exception of the organs of cutaneous sense, in terrestrial animals are special sensory cells. These cells in the process of **development** always originate from the epithelium of the external layer (**ectoderm**), which due to its position is always in contact with the environment. Every one of these cells has a small projection or receptive pili at the end facing the external surface, while at the other end in some sensory organs (organs of smell and sight) the cell gives off a process which reaches out to join processes of the nerve cells of conducting neurons.

In other organs (organs of taste and hearing) the sensory cell does not give off a central process, but is entwined by the end branches of the afferent nerve approaching it. The first type of sensory cells should be considered primary in relation to the second type. In aquatic animals this form of receptive elements is found in their skin where these elements are moistened by the surrounding fluid. There are no sensory cells in the skin of terrestrial animals and the receptive nerve fibres either terminate freely between the cells of the epithelium or have a particular kind of corpuscles at their ends. **The mesoderm** also participates in the formation of sensory organs but in a secondary way, it forms protective, supporting and auxiliary adaptations. These adaptations covering and supplementing the sensory cells, i.e. the receptors, form together with them the peripheral parts of the sensory organs: the skin, ear, eye, tongue, and nose. The visual receptor, for instance, consists of the sensory cells of the retina (cones and rods) while the peripheral part is the whole eye.

The organ of vision

Light became the stimulus which gave rise, in the animal world, to a special organ of vision. The main component of this organ in all animals are specific sensory cells which originate from the ectoderm and are capable of receiving stimuli from rays of light. For the most part these cells are surrounded by pigment which serves to channel the rays of light in a definite direction and absorb superfluous rays.

Such cells in lower animals are scattered over the body (primitive "eyes"), but eventually a depression forms, lined by sensitive cells (retina) which is reached by the nerve. In invertebrates light-refracting media appear in front of the depression (lens) for the concentration of light rays falling on the retina. Vertebrates whose eyes attain the highest development, also develop muscles which move the eye and protective adaptations (eyelids, lacrimal apparatus).

A characteristic feature of vertebrates is seen in the fact that the light-sensitive membrane of the eye (retina), which contains specific cells, does not develop directly from the ectoderm, but forms by projecting from the anterior brain vesicle.

At the first stage of development of the visual analyser (in fish) the light-sensitive cells in its peripheral end (retina) look like rods and only the visual centres are located in the brain, in the mesencephalon. Such an organ of vision is only capable of light perception and of distinguishing objects. In terrestrial animals the retina is supplemented by new light-sensitive cells, retinal cones, and new visual centres appear in the diencephalon; in mammals new visual centres appear in the cortex. Due to this the eye becomes capable of colour vision. All this is connected with the first signalling system. Finally, very special development in man is attained by the highest centres of vision in the cerebral cortex which are responsible for the origin of abstract thinking closely associated with visual images, and the written speech, which are a component of the second signalling system inherent only in man.

<u>Embryogenesis of the eye</u>. The lateral projections of the wall of the anterior brain vesicle (the parts that give rise to the diencephalon) are stretching laterally form two optic vesicles communicating by a hollow narrowed stalk with the brain. The optic nerve develops from the stalk and the retina forms from the peripheral segment of the optic vesicle. With the development .of the lens, the anterior segment of the optic vesicle projects toward the stalk and, as a result, the vesicle becomes a double-layer "optic cup".

Both layers are continuous with each other at the margin of the cup to form the rudiment of the pupil. The outer (bulging) layer of the cup develops into the pigmented layer of the retina, while the inner layer becomes the sensory layer (the retina proper). The lens forms in the anterior part of the cup in its cavity, and the vitreous body forms behind the lens.

The external coats of the eye, the vascular coat, sclera and cornea, develop from the mesoderm surrounding the optic cup together with the lens. The sclera and cornea are derived from the outer denser layer of the mesoderm, while the choroid with the ciliary body and iris develop from the inner layer of the mesoderm which is rich in vessels. In the anterior part of the embryonic eye both layers separate one from the other, as a result of which the anterior chamber forms. In this place, the outer layer of the mesoderm becomes transparent and forms the cornea. The ectoderm covering the cornea in front provides the conjunctival epithelium which extends to the posterior siurface of the eyelid.

The eyeball

The eye (*oculus*) consists of **the eyeball** (*bulbus oculi*) and **the auxiliary apparatus** surrounding it.

The eyeball is spherical in shape and is situated in the eye socket. The **anterior pole**, corresponding to the most convex point on the cornea, and the posterior pole, located lateral to the exit of the optic nerve are distinguished in the eyeball. The straight line connecting both poles is called the **optic axis**, or the **external axis** of the eye (*axis opticus*). The part lying between the posterior surface of the cornea and the retina is called the **internal axis** of the eye. This axis intersects at a sharp angle with the so-called **visual line** (*linea visus*) which passes from the object of vision, through the nodal point, to the place of the best vision in the central pit of the retina. The lines connecting both poles along the circumference of the eyeball form meridians, whereas the plane perpendicular to the optic axis is the equator of the eyeball dividing it into the anterior and posterior halves. The horizontal diameter of the equator is slightly shorter than the external optic axis (the latter is 24 mm and the former 23.6 mm); its vertical diameter is even shorter (23.3 mm). The internal optic axis of a normal eye is 21.3 mm; in myopic eyes it is longer, and in long-sighted people (hypermetropic eyes) it is shorter. Consequently, the focus of converging rays in myopic people is in front of the retina, and in hypermetropic people it is behind the retina. To achieve clear vision, the hypermetropic people must always resort to accommodation. To relieve such anomalies of sight, adequate correction by means of eyeglasses is essential.

The eyeball has three coats surrounding its inner nucleus; a fibrous outer coat, a vascular middle coat, and an inner reticular coat (the retina).

The coats of the eyeball

1. The fibrous coat (*tunica fibrosa bulbi*) forms an external sheath around the eyeball and plays a protective role. In the posterior, largest of its parts, it forms an opaque tunic called the **sclera**, and in the anterior segment, a transparent **cornea**. Both areas of the fibrous coat are separated one from the other by a shallow **circular sulcus** (*sulcus sclerae*).

4. **The sclera** consists of dense connective tissue, white in colour. Its anterior part is visible between the eye-lids and is commonly referred to as the "white of the eye". At the junction with the cornea in the thickness of the sclera there is a circular venous canal, the **sinus venosus sclerae** (Schlemmi) called Schlemm's canal. Since light must penetrate to the light-sensitive elements of the retina lying in the eyeball, the anterior segment of the fibrous tunic becomes transparent and develops into the cornea.
5. **The cornea** is a continuation of the sclera and is a transparent, rounded plate, convex toward the front and concave in the back, which, like the glass of a watch, is fitted by its edge (limbus corneae) into the anterior segment of the sclera.

2. The vascular coat of the eyeball (*tunica vasculosa bulbi*) is rich in vessels, soft, dark-coloured by the pigment contained in it. It lies immediately under the sclera and consists of three parts: **the choroid, the ciliary body,** and **the iris.**

The choroid (*chorioidea*) is the posterior largest segment of the vascular coat. Due to the constant movement of the choroid in accommodation a slit-like lymphatic perichoroidal space (spatium perichorioideale) is formed here between the layers.

The ciliary body (*corpus ciliare*), the anterior thickened part of the vascular tunic, is arranged in the shape of a circular swelling in the region where the sclera is continuous with the cornea. Its posterior edge, which forms the ciliary ring (orbiculus ciliaris), is continuous with the choroid. This place corresponds to the retinal ora serrata (see below). In front the ciliary body is connected with the external edge of the iris. Anteriorly of the ciliary ring the ciliary body carries about 70 fine radially arranged whitish ciliary processes (processus ciliares).

Due to the abundance and the particular structure of the vessels in the ciliary processes, they secrete a fluid, the aqueous humour of the chambers. This part of the ciliary body is comparable with the choroid plexus of the brain and is known as the secernent part (L secerne to separate). The other part, the accommodating part, is formed by the smooth **ciliary muscle** (*musculus ciliaris*) which lies in the thickness of the ciliary body externally of the **ciliary processes**. Formerly this muscle was divided into three portions: **external meridional** (Bruecke); **middle radial** (Ivanov) and **internal circulatory** (Miller). Now only two types of fibres are distinguished, namely, **meridional** (*fibrae meridionales*) arranged longitudinally, and **circular** (*fibrae circulares*) arranged in rings. The meridional fibres forming the principal part of the ciliary muscle, begin from the sclera and terminate posteriorly in the choroid. On contracting, they tighten the choroid and relax the sac of the lens in adjusting the eyes for short distances (**accommodation**). Circulatory fibres help accommodation, advancing the frontal part of the ciliary processes and this is why they are particularly well developed in hypermetropics who must tense their accommodation apparatus very greatly. Thanks to the elastic tendons, the muscle after contraction resumes its initial position and there is no need for an antagonist.

Fibres of both kinds intertwine and form a single muscular-elastic system which in childhood consists mostly of meridional fibres, and in old age of circulatory fibres. During the lifespan the muscle fibres become gradually atrophied and replaced by connective tissue, which explains the weakening of accommodation in old age. In females degeneration of the ciliary muscle begins 5 to 10 years earlier than in males, that is, with the onset of the menopause.

The iris is the most anterior portion of the vascular coat of the eye and is a circular vertically standing plate with a round aperture called the **pupil** (*pupilla*). The pupil is not exactly in the middle, but is slightly displaced toward the nose. The iris plays the role of a diaphragm regulating the amount of light entering the eye. Due to this, when there is strong light the pupil contracts and when the light is weak, it dilates. With its outer edge (**margo ciliaris**) the iris is connected with the ciliary body and the sclera. Its inner edge surrounding the pupil (**margo pupillaris**) is free. The iris has an **anterior surface** (*facies anterior*) facing the cornea and a **posterior surface** (*facies posterior*) adhering to the lens. The anterior surface which is visible through the transparent cornea is of different colour in different people and determines the colour of their eyes. This depends on the amount of pigment contained in the superficial layers of the iris. If there is much pigment, the eyes are brown to the point of being very dark, and, on the contrary, if the pigmentary layer is weakly developed or practically absent, then the colour tones are mixed greenish-grey and light blue. The last two colours are mainly due to the transparency of the black retinal pigment on the posterior surface of the iris. In performing the function of a diaphragm, the iris displays remarkable mobility; this is ensured by fine adaptation and the correlation of its components.

Thus, the **basis of the iris** (*stroma iridis*) consists of connective tissue with the architecture of a lattice in which vessels have been fitted radially from the periphery to the pupil. These vessels are the sole carriers of elastic elements (since the connective tissue of the stroma contains no elastic fibres) and together with the connective tissue form an elastic skeleton of the iris, permitting it to change easily in size.

The actual movements of the iris itself are accomplished by the muscle system lodged within the stroma. This system consists of smooth muscle fibres which are partly arranged in a ring around the pupil to form the **sphincter of the pupil** (*m. sphincter pupillae*) and partly fan out radially from the pupillary aperture to form the **dilator of the pupil** (*m. dilatator pupillae*). Both muscles are interrelated and affect each other: the sphincter stretches the dilator, while the dilator straightens out the sphincter. Because of this, each muscle returns to its initial position, which explains the rapidity of the movements of the iris. This integral muscle system has a punctum fixum on the ciliary body.

The sphincter of the pupil is innervated by **parasympathetic** fibres coming from the nucleus of Edinger-Yakubovich's as part of n. oculomotorius (CN 3), while **the dilator of the pupil** is innervated by **sympathetic** fibres from the sympathetic trunk.

The impermeability of the diaphragm to light is due to the presence on its posterior surface of a double layer of pigmentary epithelium. On the anterior surface washed by fluid it is covered by the endothelium of the anterior chamber.

Due to the position of the vascular membrane between the fibrous and retinal coats its pigmentary layer prevents superfluous rays from falling on the retina and the vessels are distributed to all layers of the eyeball.

The vessels and nerves of the vascular coat.

The arteries arise from branches of **the ophthalmic artery** some of which enter the eyeball from the back (**the short and long posterior ciliary arteries**), while others pass anteriorly along the margin of the cornea (**the anterior ciliary arteries**). Anastomosing among themselves around the ciliary margin of the iris, they form **the greater arterial circle of the iris** (circulus arteriosus iridis major) from which small branches reach out to the ciliary body and the iris, and around the pupillary orifice and **the lesser arterial circle of the iris** (circulus arteriosus iridis minor).

The veins form a dense network in the vascular membrane. The blood from them is carried mainly by four (or five-six) **venae vorticosae**, resembling whirlpools (vortex - whirl), which along the equator of the eyeball at equal distances obliquely perforate the sclera and drain into the orbital veins. Anteriorly the veins from the ciliary muscle drain into **the sinus venosus sclerae** (Schlemm's canal) which, in turn, drains into **the anterior ciliary veins**. Schlemm's canal also communicates with the lymphatic channel through a system of fissures in Fontana's space.

The nerves of the vascular coat contain sensory (from the trigeminal nerve), parasympathetic (from the oculomotorius nerve) and sympathetic fibres.

3. The retina is the innermost of the three coats of the eyeball adhering to the vascular coat along its entire length until it reaches the pupil. Unlike the other coats it develops from the ectoderm (from the walls of the optic cup) and according to its origin consists of two layers; the external pigmented layer (stratum pigmenti retinae) and the internal layer which is the **retina proper**. The retina proper is divided in structure and function into two parts: the posterior, which contains light-sensitive elements, constitutes the **optic part** of the retina (*pars optics retinae*) and the anterior part which does not have these elements. The junction between the two is an **idented line** (*ora serrata*) passing at the level where the choroid is continuous with the ciliary ring of the ciliary body. The optic part is almost fully transparent and opacifies only in a cadaver.

On examination with an ophthalmoscope the fundus of the eye in a living person is dark red because the blood in the vascular coat is seen through the transparent retina. On this crimson background a white round spot is visible on the fundus which is the site of the exit of the optic nerve from the retina. As it emerges the optic nerve forms **an optic disk** (*discus n. optici*) with a crater-like depression in the centre, the excavation of **the optic disc** (excavatio disci). In examination with a mirror the vessels of the retina arising from this excavation are also well visible. The fibres of the optic nerve deprived of their myelin sheath spread from the disk in all directions over the optic part of the retina. The optic disk which is about 1.7 mm in diameter lies slightly medially (toward the nose) of the posterior pole of the eye. Laterally from it and, at the same time, slightly in the temporal direction from the posterior pole, is an oval 1 mm area**, the macula**; it is reddish brown in a living person with a **pinpoint depression** (*fovea centralis*) in the centre. This is the site of sharpest acuity of vision.

There are light-sensitive visual cells in the retina, whose peripheral ends are shaped as rods and cones. Since they are situated in the external layer of the retina and adhere to the **pigmentary layer**, to reach them, the rays of light must penetrate the entire thickness of the retina. **The rods** contain visual purple (**rhodopsin**) which is responsible for the pink hue of a fresh retinal membrane in the dark; in the light it is rendered colourless. The formation of visual purple is attributed to the cells of the pigmentary layer. **The cones** do not contain visual purple.

It should be noted that there are **only cones** in the **macula** and **no rods**.

In the region of **the optic disk** there are **no light-sensitive elements at all**, as a result of which this place produces no visual sensation and is therefore called **the blind spot**.

The retinal vessels. The retina possesses its own system of blood vessels. It is supplied with arterial blood from a special small branch arising from the ophthalmic artery, **the central artery of the retina** (a. centralis retina) which penetrates the optic nerve even before the nerve emerges from the eye, and then passes along the axis of the nerve to the centre of its disk where it divides into **superior (nasal and temporal)** and **inferior (nasal and temporal) branches**. The branches of the artery reach the ora serrata.

The veins fully correspond to the arteries and are known as venulae of the same names. All the venules of the retina join to form **the central vein of the retina** (v. centralis retinae) which passes together with the artery of the same name along the axis of the optic nerve and drains into **the superior ophthalmic vein** or directly into **the sinus cavernosus**.

The refracting media of the eye

The transparent light-refracting media of the eye are the **cornea**, **the vitreous body** and **the lens** which serve to form the image on the retina, and the aqueous humour which fills the chambers of the eye and provides nutrition for the avascular structures of the eye.

A. The cornea (*cornea*) is the circular area of the anterior part of the outer fibrous layer of the eyeball; it is largely responsible for refraction of the light (80%) that enters the eye. It is transparent, owing to the extremely regular arrangement of its collagen fibers and its dehydrated state. The cornea is sensitive to touch and pain; its innervation is provided by the ophthalmic nerve (CN V1). It is avascular. Its nourishment is derived from the capillary beds at its periphery, the aqueous humor, and lacrimal fluid. The latter also provides oxygen absorbed from the air.

B. The vitreous body (*corpus vitreum*) fills the space between the lens and the retina and is an absolutely transparent mass resembling jelly. The lens presses into the anterior surface of the vitreous body as a result of which a depression, the **hyaloid fossa** (*fossa hyaloidea*) forms; its edges are joined with the capsule of the lens by a special ligament.

C. The lens (lens) is a very important light-refracting medium of the eyeball (could exchange the refractar power). It is completely transparent and shaped like a lentil or a biconvex glass. The central points of the posterior and anterior convexities are called the poles of the lens (**polus anterior and posterior**), while the peripheral circumference of lens, where both surfaces join, is called **the equator**. The axis of the lens joining both poles is 3.7 mm long when looking at a distance and 4.4 mm in accommodation, when the lens becomes more **convex**. The equatorial diameter is 9 mm. The equator plane is at a right angle to **the optical axis**.

The accessory organs of the eye

The accessory organs of the eye include the **ocular muscles,** the **fasciae,** the **eyebrows,** the **eyelids,** the **conjunctiva,** and the **lacrimal apparatus.**

The ocular muscles (musculi oculi**).** The ocular muscles are the: **levator palpebrae superioris, rectus superior, rectus medialis, rectus lateralis, rectus inferior, obliquus inferior** and **obliquus superior**

1. The levator palpebrae superioris is thin, flat, and triangular in shape. It arises from the under surface of the small wing of the sphenoid, above and in front of the optic foramen, from which it is separated by the origin of the rectus superior. At its origin, it is narrow and tendinous, but soon becomes broad and fleshy, and ends anteriorly in a wide aponeurosis which splits into three lamellae. The superficial lamella blends with the upper part of the orbital septum, and is prolonged forward above the superior tarsus to the palpebral part of the orbicularis oculi, and to the deep surface of the skin of the upper eyelid. The middle lamella, largely made up of non-striped muscular fibers, is inserted into the upper margin of the superior tarsus, while the deepest lamella blends with an expansion from the sheath of the rectus superior and with it is attached to the superior fornix of the conjunctiva.

The upper part of the sheath of the levator palpebrae becomes thickened in front and forms, above the anterior part of the muscle, a transverse ligamentous band which is attached to the sides of the orbital cavity. On the medial side it is mainly fixed **to the pulley** of **the obliquus superior**, but some fibers are attached to the bone behind the pulley and a slip passes forward and **bridges over the supraorbital notch**; on the lateral side it is fixed to the capsule of the lacrimal gland and to the frontal bone. In front of the transverse ligamentous band the sheath is continued over the aponeurosis of the levator palpebrae, as a thin connective-tissue layer which is fixed to the upper orbital margin immediately behind the attachment of the orbital septum. When the levator palpebrae contracts, the lateral and medial parts of the ligamentous band are stretched and check the action of the muscle; the retraction of the upper eyelid is checked also by the orbital septum coming into contact with the transverse part of the ligamentous band.

2. The four recti arise from a **fibrous ring** (annulus tendineus communis) which surrounds the upper, medial, and lower margins of the optic foramen and encircles the optic nerve. The ring is completed by a tendinous bridge prolonged over the lower and medial part of the superior orbital fissure and attached to a tubercle on the margin of the great wing of the sphenoid, bounding the fissure. Two specialized parts of this fibrous ring may be made out: a lower, the **ligament** or **tendon of Zinn,** which gives origin **to the rectus inferior**, part of the **rectus internus**, and the lower head of origin of the rectus lateralis; and an upper, which gives origin to the rectus superior, the rest of **the rectus medialis**, and the upper head of the rectus lateralis. This upper band is sometimes termed the **superior tendon of Lockwood.** Each muscle passes forward in the position implied by its name, to be inserted by a tendinous expansion **into the sclera**, about 6 mm from the margin of the cornea.

Between the two heads of **the rectus lateralis** is a narrow interval, through which pass the two divisions of **the oculomotor nerve, the nasociliary nerve, the abducent nerve, and the ophthalmic vein.** Although these muscles present a common origin and are inserted in a similar manner into the sclera, there are certain differences to be observed in them as regards their length and breadth. **The rectus medialis** is the broadest, **the rectus lateralis** the longest, and the rectus superior the thinnest and narrowest.

3. The obliquus oculi superior (superior oblique) is a fusiform muscle, placed at the upper and medial side of the orbit. It arises immediately above the margin of the optic foramen, above and medial to the origin of the rectus superior, and, passing forward, ends in a rounded tendon, which plays in a fibrocartilaginous ring or **pulley** attached to the trochlear fovea of the frontal bone. The contiguous surfaces of the tendon and ring are lined by a delicate mucous sheath, and enclosed in a thin fibrous investment. The tendon is reflected backward, lateralward, and downward beneath the rectus superior to the lateral part of the bulb of the eye, and is inserted **into the sclera, behind the equator** of the eyeball, the insertion of the muscle lying between the rectus superior and rectus lateralis.

The obliquus oculi inferior (inferior oblique) is a thin, narrow muscle, placed near the anterior margin of the floor of the orbit. It arises from the orbital surface of the **maxilla**, lateral to the lacrimal groove. Passing lateralward, backward, and upward, at first between the rectus inferior and the floor of the orbit, and then between the bulb of the eye and the rectus lateralis, it is inserted into the lateral part of the sclera between the rectus superior and rectus lateralis, near to, but somewhat behind the insertion of the obliquus superior.

Actions. The levator palpebrae raises the upper eyelid, and is the direct antagonist of the orbicularis oculi. **The four recti** are attached to the bulb of the eye in such a manner that, acting singly, they will **turn** its corneal surface either **upward, downward, medialward, or lateralward, as expressed by their names**. The movement produced by the rectus superior or rectus inferior is not quite a simple one, for inasmuch as each passes obliquely lateralward and forward to the bulb of the eye, the elevation or depression of the cornea is accompanied by a certain deviation medialward, with a slight amount of rotation. **These latter movements** are corrected by **the obliqui**, the obliquus inferior correcting the medial deviation caused by the rectus superior and the obliquus superior that caused by the rectus inferior.

The contraction of **the rectus lateralis** or **rectus medialis**, on the other hand, produces a **purely horizontal movement**.

If any two neighboring recti of one eye act together they carry the globe of the eye in the diagonal of these directions, viz., upward and medialward, upward and lateralward, downward and medialward, or downward and lateralward. Sometimes the corresponding recti of the two eyes act in unison, and at other times the opposite recti act together. Thus, in turning the eyes to the right, the rectus lateralis of the right eye will act in unison with the rectus medialis of the left eye; but if both eyes are directed to an object in the middle line at a short distance, the two recti mediales will act in unison. The movement of circumduction, as in looking around a room, is performed by the successive actions of the four recti. The obliqui rotate the eyeball on its antero-posterior axis, the superior directing the cornea downward and lateralward, and the inferior directing it upward and lateralward; these movements are required for the correct viewing of an object when the head is moved laterally, as from shoulder to shoulder, in order that the picture may fall in all respects on the same part of the retina of either eye.

Nerves

The levator palpebrae superioris, obliquus inferior, and the recti superior, inferior, and medialis are supplied by **the oculomotor nerve**;

the obliquus superior, by **the trochlear nerve**;

the rectus lateralis, by **the abducent nerve**.

The **fascia bulb** (capsule of Ténon) is a thin membrane which envelops the bulb of the eye from the optic nerve to the ciliary region, separating it from the orbital fat and forming a socket in which it plays. Its inner surface is smooth, and is separated from the outer surface of the sclera by the **periscleral lymph space.** This lymph space is continuous with the subdural and subarachnoid cavities, and is traversed by delicate bands of connective tissue which extend between the fascia and the sclera. The fascia is perforated behind by the ciliary vessels and nerves, and fuses with the sheath of the optic nerve and with the sclera around the entrance of the optic nerve. In front it blends with the ocular conjunctiva, and with it is attached to the ciliary region of the eyeball. It is perforated by the tendons of the ocular muscles, and is reflected backward on each as a tubular sheath. The sheath of the obliquus superior is carried as far as the fibrous pulley of that muscle; that on the obliquus inferior reaches as far as the floor of the orbit, to which it gives off a slip. The sheaths on the recti are gradually lost in the perimysium, but they give off important expansions. The expansion from the rectus superior blends with the tendon of the levator palpebrae; that of the rectus inferior is attached to the inferior tarsus. The expansions from the sheaths of the recti lateralis and medialis are strong, especially that from the latter muscle, and are attached to the lacrimal and zygomatic bones respectively. As they probably check the actions of these two recti they have been named the **medial** and **lateral check ligaments.** Lockwood has described a thickening of the lower part of the facia bulbi, which he has named the **suspensory ligament of the eye.** It is slung like a hammock below the eyeball, being expanded in the center, and narrow at its extremities which are attached to the zygomatic and lacrimal bones respectively.

The **orbital fascia** forms the periosteum of the orbit. It is loosely connected to the bones and can be readily separated from them. Behind, it is united with the dura mater by processes which pass through the optic foramen and superior orbital fissure, and with the sheath of the optic nerve. In front, it is connected with the periosteum at the margin of the orbit, and sends off a process which assists in forming the orbital septum. From it two processes are given off; one to enclose the lacrimal gland, the other to hold the pulley of the obliquus superior in position.

The **eyebrows** (supercilia) are two arched eminences of integument, which surmount the upper circumference of the orbits, and support numerous short, thick hairs, directed obliquely on the surface. The eyebrows consist of thickened integument, connected beneath with the orbicularis oculi, corrugator, and frontalis muscles.

The **eyelids** (palpebrae) are two thin, movable folds, placed in front of the eye, protecting it from injury by their closure. The upper eyelid is the larger, and the more movable of the two, and is furnished with an elevator muscle, the levator palpebrae superioris. When the eyelids are open, an elliptical space, the palpebral **fissure** (rima palpebrarum), is left between their margins, the angles of which correspond to the junctions of the upper and lower eyelids, and are called the **palpebral commissures** or **canthi.**

The **lateral palpebral commissure** (commissura palpebrarum lateralis; external canthus) is more acute than the medial, and the eyelids here lie in close contact with the bulb of the eye: but the **medial palpebral commissure** (commissura palpebrarum medialis; internal canthus) is prolonged for a short distance toward the nose, and the two eyelids are separated by a triangular space, the **lacus lacrimalis**. At the basal angles of the lacus lacrimalis, on the margin of each eyelid, is a small conical elevation, the **lacrimal papilla,** the apex of which is pierced by a small orifice, the **punctum lacrimale,** the commencement of the lacrimal duct.

The **eyelashes** (cilia) are attached to the free edges of the eyelids; they are short, thick, curved hairs, arranged in a double or triple row: those of the upper eyelid, more numerous and longer than those of the lower, curve upward; those of the lower eyelid curve downward, so that they do not interlace in closing the lids. Near the attachment of the eyelashes are the openings of a number of glands, the **ciliary glands,** arranged in several rows close to the free margin of the lid; they are regarded as enlarged and modified sudoriferous glands.

Structure of the eyelids.—the eyelids are composed of the following structures taken in their order from without inward: integument, areolar tissue, fibers of the orbicularis oculi, tarsus, orbital septum, tarsal glands and conjunctiva. The upper eyelid has, in addition, the aponeurosis of the levator palpebrae superioris.

The **integument** is extremely thin, and continuous at the margins of the eyelids with the conjunctiva. The **subcutaneous areolar tissue** is very lax and delicate, and seldom contains any fat. The **palpebral fibers of the orbicularis oculi** are thin, pale in color, and possess an involuntary action.

The **tarsi** (tarsal plates) are two thin, elongated plates of dense connective tissue, about 2.5 cm. In length; one is placed in each eyelid, and contributes to its form and support. The **superior tarsus** (tarsus superior; superior tarsal plate), the larger, is of a semilunar form, about 10 mm. In breadth at the center, and gradually narrowing toward its extremities. To the anterior surface of this plate the aponeurosis of the levator palpebrae superioris is attached. The **inferior tarsus** (tarsus inferior; inferior tarsal plate), the smaller, is thin, elliptical in form, and has a vertical diameter of about 5 mm. The free or ciliary margins of these plates are thick and straight. The attached or orbital margins are connected to the circumference of the orbit by the orbital septum. The lateral angles are attached to the zygomatic bone by the lateral palpebral raphé. The medial angles of the two plates end at the lacus lacrimalis, and are attached to the frontal process of the maxilla by the medial palpebral ligament

The **orbital septum** (septum orbitale; palpebral ligament) is a membranous sheet, attached to the edge of the orbit, where it is continuous with the periosteum. In the upper eyelid it blends by its peripheral circumference with the tendon of the levator palpebrae superioris and the superior tarsus, in the lower eyelid with the inferior tarsus. Medially it is thin, and, becoming separated from the medial palpebral ligament, is fixed to the lacrimal bone immediately behind the lacrimal sac. The septum is perforated by the vessels and nerves which pass from the orbital cavity to the face and scalp. The eyelids are richly supplied with blood.

The tarsal glands (*glandulae tarsales* [*Meibomi*]; *meibomian glands*).—the tarsal glands are situated upon the inner surfaces of the eyelids, between the tarsi and conjunctiva, and may be distinctly seen through the latter on inverting the eyelids, presenting an appearance like parallel strings of pearls. There are about thirty in the upper eyelid, and somewhat fewer in the lower. They are imbedded in grooves in the inner surfaces of the tarsi, and correspond in length with the breadth of these plates; they are, consequently, longer in the upper than in the lower eyelid. Their ducts open on the free magins of the lids by minute foramina.

Structure. The tarsal glands are modified sebaceous glands, each consisting of a single straight tube or follicle, with numerous small lateral diverticula. The tubes are supported by a basement membrane, and are lined at their mouths by stratified epithelium; the deeper parts of the tubes and the lateral offshoots are lined by a layer of polyhedral cells.

The **conjunctiva** is the mucous membrane of the eye. It lines the inner surfaces of the eyelids or palpebrae, and is reflected over the forepart of the sclera and cornea.

The **palpebral portion** (*tunica conjunctiva* palpebrarum) is thick, opaque, highly vascular, and covered with numerous papillae, its deeper part presenting a considerable amount of lymphoid tissue. At the margins of the lids it becomes continuous with the lining membrane of the ducts of the tarsal glands, and, through the lacrimal ducts, with the lining membrane of the lacrimal sac and nasolacrimal duct. At the lateral angle of the upper eyelid the ducts of the lacrimal gland open on its free surface; and at the medial angle it forms a semilunar fold, the **plica semilunaris.** The line of reflection of the conjunctiva from the upper eyelid on to the bulb of the eye is named the **superior fornix,** and that from the lower lid the **inferior fornix.**

The **bulbar portion** (tunica conjunctiva bulbi). -upon the sclera the conjunctiva is loosely connected to the bulb of the eye; it is thin, transparent, destitute of papillae, and only slightly vascular. Upon the *cornea*, the conjunctiva consists only of epithelium, constituting the epithelium of the cornea, already described. Lymphatics arise in the conjunctiva in a delicate zone around the cornea, and run to the ocular conjunctiva.

In and near **the fornices**, but more plentiful in the upper than in the lower eyelid, a number of convoluted tubular glands open on the surface of the conjunctiva. Other glands, analogous to lymphoid follicles, and called by Henle **trachoma glands,** are found in the conjunctiva, and, according to Strohmeyer, are chiefly situated near the medial palpebral commissure. They were first described by brush, in his description of Peyer's patches of the small intestine, as "identical structures existing in the under eyelid of the ox."

The **caruncula lacrimalis** is a small, reddish, conical-shaped body, situated at the medial palpebral commissure, and filling up the **lacus lacrimalis.** It consists of **a small island** of skin containing sebaceous and sudoriferous glands, and is the source of the whitish secretion which constantly collects in this region. A few slender hairs are attached to its surface. Lateral to the caruncula is **a slight semilunar fold** of conjunctiva, the concavity of which is directed toward the cornea; it is called the **plica semilunaris.** Müller found smooth muscular fibers in this fold; in some of the domesticated animals it contains a thin plate of cartilage. **The nerves** in the conjunctiva are numerous and form rich plexuses.

The lacrimal apparatus

The **lacrimal apparatus** (apparatus lacrimalis) consists of (*a*) the **lacrimal gland,** which secretes the tears, and its excretory ducts, which convey the fluid to the surface of the eye; (*b*) the **lacrimal ducts,** the **lacrimal sac,** and the **nasolacrimal duct,** by which the fluid is conveyed into the cavity of the nose.

The lacrimal gland (*glandula lacrimalis*).—the lacrimal gland is lodged in the lacrimal fossa, on the medial side of the zygomatic process of the frontal bone. It is of an oval form, about the size and shape of an almond, and consists of two portions, described as the superior and inferior lacrimal glands. The **superior lacrimal gland** is connected to the periosteum of the orbit by a few fibrous bands, and rests upon the tendons of the recti superioris and lateralis, which separate it from the bulb of the eye. The **inferior lacrimal gland** is separated from the superior by a fibrous septum, and projects into the back part of the upper eyelid, where its deep surface is related to the conjunctiva. The ducts of the glands, from six to twelve in number, run obliquely beneath the conjunctiva for a short distance, and open along the upper and lateral half of the superior conjunctival fornix.

Structures of the lacrimal gland - in structure and general appearance the lacrimal resembles the serous salivary glands. In the recent state the cells are so crowded with granules that their limits can hardly be defined. They contain oval nuclei, and the cell protoplasm is finely fibrillated.

The lacrimal ducts (ductus lacrimalis; lacrimal canals**).**—the lacrimal ducts, one in each eyelid, commence at minute orifices, termed **puncta lacrimalia,** on the summits of the **papillae lacrimales,** seen on the margins of the lids at the lateral extremity of the lacus lacrimalis. The **superior duct,** the smaller and shorter of the two, at first ascends, and then bends at an acute angle, and passes medialward and downward to the lacrimal sac. The **inferior duct** at first descends, and then runs almost horizontally to the lacrimal sac. At the angles they are dilated into **ampullae;** their walls are dense in structure and their mucous lining is covered by stratified squamous epithelium, placed on a basement membrane. Outside the latter is a layer of striped muscle, continuous with the lacrimal part of the orbicularis oculi; at the base of each lacrimal papilla the muscular fibers are circularly arranged and form a kind of sphincter.

The lacrimal sac (saccus lacrimalis**).**—the lacrimal sac is the upper dilated end of the nasolacrimal duct, and is lodged in a deep groove formed by the lacrimal bone and frontal process of the maxilla. It is oval in form and measures from 12 to 15 mm. In length; its upper end is closed and rounded; its lower is continued into the nasolacrimal duct. Its superficial surface is covered by a fibrous expansion derived from the medial palpebral ligament, and its deep surface is crossed by the lacrimal part of the orbicularis oculi, which is attached to the crest on the lacrimal bone.

Structure. - The lacrimal sac consists of a fibrous elastic coat, lined internally by mucous membrane: the latter is continuous, through the lacrimal ducts, with the conjunctiva, and through the nasolacrimal duct with the mucous membrane of the nasal cavity.

The n**asolacrimal duct** (ductus nasolacrimalis; nasal duct).—the nasolacrimal duct is a membranous canal, about 18 mm. In length, which extends from the lower part of the lacrimal sac to the inferior meatus of the nose, where it ends by a somewhat expanded orifice, provided with an imperfect valve, the **plica lacrimalis** (Hasneri), formed by a fold of the mucous membrane. It is contained in an osseous canal, formed by the maxilla, the lacrimal bone, and the inferior nasal concha; it is narrower in the middle than at either end, and is directed downward, backward, and a little lateralward. The mucous lining of the lacrimal sac and nasolacrimal duct is covered with columnar epithelium, which in places is ciliated.

The pathway of visual information

Light stimulates the light sensitive cells located in the retina. Before fall in on the retina the light pass trough different transparent media of eye ball: cornea, the aqueous humor of anterior chamber, puple, lens and vitreous body. The nerve elements of retina form a chain of **three neurons**. First cells are light sensitive components **rods and cones**, which constitute the receptor for visual analyzer. After, **bipolar** cells make connection to **ganglionar** (third element) multipolar neurons. The processes of the last ones make up the **optic nerve**. After leaving the orbits, the optic nerves decussate forming **the optic chiasma**. Only the medial parts of nerves running from **medial halves of retina decussate**. The opposite (lateral) sides remain **uncrossed**. Next structures that direct visual fibers are **optic tracts**. Analyzing of optic information starts in subcortical centers of brain stem: su**perior colliculli (midbrain), lateral geniculate body (methathalamus) and pulvinar thalamy**.

The terminal, cortical level of control and analyzing of vision is cortex around of calcarinus groove, area 17 of the **occipital lobe**. Commutation between subcortical and cortical centers is performed by **radiatio optica** (Gratiole bundle), that pass through end of posterior crus of internal capsule.

The organ of gravitation and balance and the organ of hearing

The organ consists of two analysers: **the analyser of gravitation** (i.e. the sense of gravitational attraction) and balance, and the **analyser of hearing** (**auditory analyser**). Until recently both analysers were regarded as one **organ of hearing and balance** (**organum vestibulocochleare**). This is how it is still described in all textbooks of anatomy, but with the appearance of space medicine and, particularly, space anatomy, which studies the influences of gravitational overloads on the structure of the organism, certain patterns were revealed in the adaptation of the body to the effect of gravitational overloads occurring in high-altitude and spaceflights, when the pilot or fliers takes off from the ground and overcomes the gravitational attraction. This is why in our textbook both these analysers are studied independently, because each of them has its own receptor, conductor and cortical end.

The combined description of them as of a single organ, however, has its justification, because of the character of their development. At first both analysers formed as a single organ in one bone, the temporal bone, where they are located in man to this day. Eventually they differentiated into **two different analysers both** of which are closely interconnected as though they form a single organ. In man and vertebrate animals a substantial part of this organ is the labyrinth which contains dual-type receptors: one of them (**the organ of Corti**) is a delicate arrangement serving for the appreciation of sound stimuli; the others (**maculae and cristae ampullares**) are the receptor devices of the stato-kinetic apparatus necessary for the appreciation of the forces of gravitational attraction, and for maintaining the balance and orientation of the body in space. At the lower stages of development these two functions had not been differentiated from each other yet, but the static function is primary. The prototype of the labyrinth in this sense is the static vesicle (the oto- or statocyst) which is commonly found in invertebrate acquatic animals, e.g. mollusks.

In vertebrates this originally simple form of the vesicle becomes much more complicated in accord with the complication of the functions of the labyrinth. Genetically the vesicle arises from the ectoderm first by protruding and then breaking off. This is followed by the separation of the semicircular canals which are special tube-like appendages of the static apparatus. Hagfishes have just one semicircular canal connected with a single vesicle and that is why they can move only in one direction. Two semicircular canals appear in cyclostomata, so they can easily move their body in two directions. Finally, beginning with fish, all the rest of the vertebrates have three semcircular canals developing corresponding to the three dimensions existingin nature, which permit them to move in any direction. As a result, a vestbule is thus formed for the labyrinth and the semicircular canals which havetheir own special nerve, **the vestibular nerve** (n. vestibularis) which is the vestibular part of the auditory nerve. With the emergence onto land, when terrestrial animals began moving by means of limbs and man acquired an upright posture the importance of balance increased. The static receptor does not change in structure in the terrestrial vertebrates because it is already fully formed in fish. This, however, made the structure of the brain centres that automatically regulate the posture of the body even more complicated.

In man the centres controlling the body posture reach the highest development. The organ of balance in aquatic animals, forms in connection with their free movement in space, but the auditory apparatus, which is at an embryonic stage in fish, develops only with the emergence of animals onto land when the direct appreciation of air vibrations becomes possible. The auditory apparatus gradually separates from the remainder of the labyrinth, twisting spirally into a coil like a snail shell. With the change from water to an air medium, the internal ear is joined by a sound-conducting apparatus. Thus, the middle ear appears beginning with amphibians; this is the tympanic cavity with the tympanic membrane and the auditory ossicles. The auditory apparatus reaches the highest development in mammals with a spiral cochlea coupled with a complex sound-sensory device. They possess a separate nerve, **the cochlear nerve** (n. cochlearis), and several auditory centres in the brain, subcortical (in the mesencephalon and metencephalon) and cortical. Mammals also develop the external ear with a deep auditory meatus and concha of the auricle. The auricle is the latest acquisition in time which plays the part of a megaphone to amplify sound and also to protect the external auditory meatus. In terrestrial mammals the auricle is supplied with special muscles and moves easily in the direction of the sound (to prick up one's ears). Mammals living in water or underground have no auricle. In man and higher primates it is reduced in size and is immobile. The origin of oral speech among human beings was paralleled by the maximum development of auditory centres, particularly in the cerebral cortex; they constitute part of the second signalling system, the superior supplement to the thinking of animals. Thus, despite the reduction of certain parts of the ear, the auditory analyser proves to be most developed in man.

The embryogenesis of the organ of hearing and balance in man is generally similar to phylogenesis. In about the third week of embryonic life an auditory vesicle, the germ of the labyrinth, appears from the ectoderm on both sides of the posterior cerebral vesicle. By the end of the fourth week the enclolymphatic duct (ductus endolymphaticus) and three semicircular canals grow out of it.

The upper part of the auditory vesicle into which the semicircular canals drain is the germ of the utriculus; it separates at the place where the endolymphatic duct departs from the lower part of the vesicle, the rudiment of the future sacculus. The narrowed place between these two parts transforms into the utriculosaccular duct (ductus utriculosaccularis). In the fifth week of embryonic life at first a small protrusion (lagaena) forms on the anterior segment of the auditory vesicle corresponding to the sacculus, which soon develops to form the spiral duct of the cochlea (ductus cochlearis). At first the walls of the cavity of the vesicle of the labyrinth are covered with similar epithelial cells, some of which due to the ingrowth of peripheral processes of the nerve cells from the auditory ganglion lying on the anterior surface of the labyrinth, transform into sensory cells (**organ of Corti**).

The mesenchyme adjoining the membranous labyrinth transforms into connective tissue, creating perilymphatic spaces around the utriculus, sacculus and semicircular canals that had formed.

In the sixth month of embryonic life an osseous labyrinth arises from the perichondrium of the cartilaginous auditory capsule of the cranium by perichondral ossification. The osseous labyrinth grows around the membranous labyrinths with perilymphatic spaces duplicating the general form of the latter. The middle ear, i.e. the tympanic cavity with the auditory tube, develops from the first pharyngeal pouch and the lateral part of the superior wall of the pharynx. Consequently, the epithelium of the mucous coat of the middle ear cavities derives from **the entoderm**. The auditory ossicles in the tympanic cavity are derived from the cartilage of the first (malleus and the anvil) and **the second** (stirrup) **- visceral arches**. The external ear originates from **the first branchial pouch**.

The peripheral part of the organ of hearing and gravitation is located in the temporal bone and is divided into three parts: **the external, middle** and **internal ear**. The first two serve exclusively for **conducting** sound vibrations, and the third, in addition to this, contains sound-sensory and static apparatuses which are the peripheral parts of **the auditory and statokinetic analysers**.

The organ of hearing

The external ear

The external ear consists of the **auricle** and the **external auditory meatus**.

The **auricle** (auricula) commonly called the ear, is formed of elastic cartilage covered with skin. This cartilage determines the external shape of the auricle and its projections: the free curved margin called the **helix**, the **anthelix**, located parallel to it, the anterior prominence, the **tragus**, and the **antitragus** situated behind it. Downward the ear terminates as the lobule which has no cartilage; this is a characteristic progressive developmental sign for man. In the depression on the lateral surface of the auricle (**the concha auriculae)**, behind the tragus, is the external auditory meatus around which the remainder of the rudimentary muscles has been preserved. They are of no functional significance. Since the auricle of man is immobile, some authors consider it to be a rudimentary formation, but others disagree with this point of view because the cartilaginous skeleton of the human ear is well defined.

The **external auditory meatus** (*meatus acusticus externus*) consists of two parts: **cartilaginous** and **bony**. The cartilaginous auditory meatus is a continuation of the auricular cartilage in the form of a groove open upward and to the back. Its internal end is joined by means of connective tissue with the edge of the tympanic part of the temporal bone. The cartilaginous auditory meatus constitutes two thirds of the whole external auditory meatus. The bony auditory meatus which constitutes two thirds of the entire length of the auditory meatus opens to the exterior by means of the porus acusticus externus on the periphery of which runs a circular bony **tympanic groove** (sulcus tympanicus).

The direction of the whole auditory meatus is frontal in general but it does not advance in a straight line; it winds in the form of letter "S" both horizontally and vertically. Because of the curves of the auditory meatus, the deeply situated tympanic membrane can only be seen by pulling the auricle backward, outward and upward. The skin that covers the auricle continues into the external auditory meatus. In the cartilaginous part of the meatus the skin is very rich both in sebaceous glands and in a particular kind of glands, the ceruminous glands (glandulae ceruminosae), which produce a yellowish secretion, cerumen (ear wax). In this part there are also short hairs growing in the skin which prevent tiny particles from getting into the organ. In the bony part of the duct the skin thins out considerably and extends without interruption onto the external surface of the tympanic membrane which closes the medial end of the meatus.

The tympanic membrane

The tympanic membrane or **ear drum** (membrana tympani) is located at the junctions of the external and middle ears. Its edge fits into the sulcus tympanicus at the end of the external auditory meatus as into a frame. The tympanic membrane is secured in the sulcus tympanicus by a fibrocartilaginous ring (anulus fibrocartilagineus). The membrane is inclined because of the oblique position of the medial end of the auditory meatus, but in newborns it is almost horizontal. The tympanic membrane in an adult is oval in shape and measures 11 mm in length and 9 mm in breadth. It is a thin semitransparent sheet in which the centre, called **the umbo** (umbo membranae tympani) is drawn in like a shallow funnel. Its external surface is covered by a thinned-out continuation of the **skin covering** the auditory meatus (**stratum cutaneum**), the internal surface by the **mucous lining** of the tympanic cavity (**stratum mucosum**).

The substance of the membrane itself between the two layers consists of fibrous connective tissue, the fibres of which in the peripheral part of the membrane run in **a radial direction** and in the central part in a **circular direction**. In the upper part the tympanic membrane contains no fibrous fibres and consists only of the skin and mucous layers and a thin stratum of loose tissue between them; this part of the tympanic membrane is softer and less tightly stretched; it has therefore been named the flaccid part (**pars flaccida**) in contrast to the remaining tightly stretched tense part (**pars tensa**).

The middle ear

The middle ear consists of the tympanic cavity and the auditory tube through which it communicates with the nasopharynx.

The tympanic cavity (cavitas tympani) is situated in the base of the pyramid of the temporal bone between the external auditory meatus and the labyrinth (internal ear). It contains a chain of three small ossicles transmitting sound vibrations from the tympanic membrane to the labyrinth. The tympanic cavity is very small (volume of about 1 cm3) and resembles a tambourine propped up on its side and greatly inclined toward the external auditory meatus. Six walls are distinguished in the tympanic cavity.

1. **The lateral**, or membranous, wall (**paries membranaceus**) of the tympanic cavity is formed by the tympanic membrane and the bony plate of the external auditory meatus. The upper dome-like, expanded part of the tympanic cavity, the epitympanic recess (recessus epitympanicus), contains two auditory ossicles: the head of the malleus and the anvil. In disease the pathological changes in the middle ear are most evident in the epitympanic recess.

2. **The medial wall** of the tympanic cavity belongs to the labyrinth and is therefore called the labyrinthine wall (**paries labyrinthicus**). It has two openings: a round one, the fenestra cochleae opening into the cochlea and closed with the secondary tympanic membrane (membrana tympani secundaria), and an oval fenestra vestibuli opening into the vestibulum labyrintii. The base of the third auditory ossicle, the stapes, is inserted in this opening. The fenestra cochlea is the most vulnerable spot in the bony wall of the internal -ear.

3. **The posterior, or mastoid**, wall of the tympanic cavity (**parties mastoideus**) has an eminence, the pyramid of **the tympanum** (eminentia pyramidalis), containing the stapedius muscle. The epitympanic recess is continuous posteriorly with the **tympanic antrum** (*antrum mastoideum*) into which the mastoid air cells (**cellulae mastoideae**) open. The tympanic antrum is a small cavity protruding toward the mastoid process from whose external surface it is separated by a layer of bone bordering with the posterior wall of the auditory meatus immediately behind the suprameatal spine where the antrum is usually cut open in suppuration of the mastoid process.

4. **The anterior**, or **carotid**, wall of the tympanic cavity (**paries caroticus**) is called so because it is closely adjoined by the internal carotid artery separated from the cavity of the middle ear only by a thin bony plate. In the upper part of this wall is the tympanic opening of the pharyngotympanic tube (***ostium tympanicum tubae auditivae***) which in newborns and infants gapes; this explains the frequent penetration of infection from the nasopharynx into the cavity of the middle ear and further into the skull.

5. **The roof**, or tegmental wall of the tympanic cavity (**paries tegmentalis**) corresponds on the anterior surface of the pyramid to the tegmen tympani and separates the tympanic cavity from the cranial cavity.

6. **The floor**,or **jugular** wall of the tympanic cavity (*paries jugularis*) faces the base of the skull in close proximity to the jugular fossa.

The three tiny auditory ossicles in the tympanic cavity are called the **malleus, incus, and stapes**, the Latin for hammer, anvil and stirrup, respectively, which they resemble in shape.

1. The malleus has a rounded **head** (caput mallei) which by means of a **neck** (collum mallei) is joined to the **handle** (manubrium mallei).

2. The incus has a **body** (corpus inoudis) and two diverging processes, a short (**crus breve**), and a long process (**crus longum**). The short process projects backward and abuts upon the fossa. The long process runs parallel to the handle of the malleus, medially and posteriorly of it and has a small oval thickening on its end, the **lenticular process** (processus lenticularis), which articulates with the stapes.

3. The stapes justifies its name in shape and consists of a small **head** (**caput stapedis**), carrying an articulating surface for the lenticular process of the incus and two limbs: an anterior, less curved limb (**crus anterius**), and a posterior more curved limb (**crus posterius**). The limbs are attached to an **oval base** (**basis stapedis**) fitted into the fenestra vestibuli.

In places where the auditory ossicles articulate with one another, two true joints of limited mobility are formed: the incudomalleolar joint (**articulation incudomallearis**) and the incudostapedial joint (**articulatio incudostapedia**).

The base of the stapes is joined with the edges of fenestra vestibuli by means of connective tissue to form the **tymanostapedial synclesmosis** (syndesmosis tympanostapedia). The auditory ossicles are attached, moreover, by several separate ligaments. On the whole, all three ossicles form a more or less mobile chain running across the tympanic cavity from the tympanic membrane to the labyrinth. The mobility of the ossicles becomes gradually reduced from malleus to stapes, as the result of which the organ of Corti located in the internal ear is protected from excessive concussions and harsh sounds.

The chain of ossicles performs two functions:

(1) the conduction of sound through the bones and

(2) the mechanical transmission of sound vibrations to the fenestra cochlea.

The latter function is accomplished by two small muscles connected with the auditory ossicles and located in the tympanic cavity; they regulate the movement of the chain of ossicles. One of them, **the tensor tympani muscle**, lies in the canal for the tensor tympany (semicanalis m. tensoris) constituting the upper part of the musculotubal canal of the temporal bone; its tendon is fastened to the handle of the malleus near the neck. This muscle pulls the handle of the malleus medially, thus tensing the tympanic membrane. At the same time all the system of ossicles moves medially and the stapes presses into the fenestra cochlea. The muscle is innervated from the third division of **the trigeminal nerve (**mandibular nerve**)** by a small branch of the nerve supplied to the tensor tympani muscle.

The other muscle, **the stapedius muscle**, is lodged in the pyramid of the tympanum and fastened to the posterior limb of the stapes at the head. In function this muscle is an **antagonist** of the preceding one and accomplishes a reverse movement of the ossicle in the middle ear in the direction of the fenestra cochlea. The stapedius muscle is innervated from **the facial nerve**, which, passing nearby, sends small branch to the muscle.

The muscles of the middle ear perform a variety of functions:

(1) maintain the normal tonus of the tympanic membrane and the chain of auditory ossicles;

(2) protect the internal ear from excessive sound stimuli and

(3) accommodate the sound-conducting apparatus to sounds of different intensity and pitch.

The basic principle of the work of the middle ear on the whole consists in conducting sound from the tympanic cavity to the fenestra cochlea.

The auditory, or Eustachian, or pharyngotympanic tube (tuba auditiva, Eustachii) which lends the name "eustachitis" to inflammation of the tube, lets the air pass from the pharynx into the tympanic cavity, thus equalizing the pressure in this cavity with the atmospheric pressure, which is essential for the proper conduction to the labyrinth of the vibrations of the tympanic membrane. The auditory tube consists of osseous and cartilaginous parts which are joined with each other. At the site of their junction, called the **isthmus of the tube** (isthmus tubae), the canal of the tube is narrowest. The bony part of the tube, beginning with its tympanic opening (**ostium tympanicum tubae auditivae**), occupies the large inferior portion of the muscular-tube canal (**semicanalis tubae auditivae**) of the temporal bone. **The cartilaginous part**, which is a continuation of the bony part, is formed of elastic cartilage.

The tube widens downward and terminates on the lateral wall of **the nasopharynx** as **the pharyngeal opening** (ostium pharyngeum tubae auditivae); the edge of the cartilage pressing into the pharynx forms the **tubae elevation** (torus tubarius). The mucosa lining the auditory tube is covered by ciliated epithelium and contains **mucous glands** (glandulae tubariae mucosae) and **lymphatic follicles** which accumulate in large amounts at the pharyngeal ostium to form **the tube tonsil** (tonsilla tubaria). Fibers **of the tensor palati muscle** arise from the cartilaginous part of the tube and, consequently, when this muscle contracts in **swallowing**, the lumen of the tube can expand, which is conducive to the passage of air into the tympanic cavity.

The internal ear

The internal ear, or **the labyrinth**, is located in the depth of the pyramid of the temporal bone between the tympanic cavity and the internal auditory meatus, through which the auditory nerve emerges from the labyrinth. **A bony** and **membranous labyrinth** is distinguished with the latter enclosed in the former.

The bony labyrinth (labyrinthus osseus) comprises a number of very small inter-communicating cavities, whose walls are of compact bone. Three parts are distinguished in the labyrinth: **the vestibule**, **semicircular canals**, and **the cochlea**. The cochlea lies in front of, medially to, and somewhat below the vestibule; the semicircular canals are situated behind, laterally to and above the vestibule.

1. The vestibule (vestibulum) which forms the middle part of the labyrinth is a small, approximately oval-shaped cavity, communicating in back through five openings with the semicircular canals. In front it communicates through a wider opening with the canal of the cochlea. On the lateral vestibular wall facing the tympanic cavity is the opening mentioned above, **the fenestra vestibuli**, which is occupied by the base of the stapes. Another opening, **fenestra cochleae**, closed by the secondary tympanic membrane is located at the beginning of the cochlea. The **vestibular crest** (crista vestibuli) passing on the inner surface of the medial vestibular wall divides this cavity in two, of which the posterior connected with the semicircular canals is called **the elliptical recess** (recessus ellipticus) and the anterior, nearest the cochlea, is called **the spherical recess** (recessus sphericus). **The aqueduct of the vestibule** begins in the elliptical recess as a small opening (apertura interna aqueductus vestibuli), passes through the bony substance of the pyramid, and terminates on its posterior surface. Under the posterior end of the crest on the floor of the vestibule is a small depression called the **cochlear recess** (recessus cochlearis).

2. The semicircular canals (canales semicirculares ossei) are three arch-like bony passages situated in three mutually perpendicular planes. **The anterior semicircular canal** (canalis semicircularis anterior) is directed vertically at right angles to the axis of the pyramid of the temporal bone; **the posterior semicircular canal** (canalis semicircularis posterior), which is also vertical, is situated nearly parallel to the posterior surface of the pyramid, while **the lateral canal** (canalis semicircularis lateralis) lies horizontally, protruding toward the tympanic cavity. Each canal has two limbs.

The bony labyrinth may easily be separated as a whole from the spongy substance of the pyramid surrounding it in the skulls of children. The external shape of the labyrinth may also be studied conveniently on its metal moulds obtained by means of corrosion, which open into the vestibule by five apertures only; however, because the neighbouring ends of the anterior and posterior canals join to form a common limb termed **the crus commune**. One of the limbs of each canal before joining the vestibule forms a dilatation called **an ampulla**. An ampullated limb is called **crus ampullare**, and a non-ampulated limb is termed **crus simplex**.

3. The cochlea is as a spiral bony canal (canalis spiralis cochleae) which, beginning from the vestibule, winds up like **the shell** of a snail into **two and a half coils**. The bony pillar around which the coils wind lies horizontally and is called the modiolus. An osseous **spiral lamina** (lamina spiralis ossea) projects from **the modiolus** into the cavity of the canal along the entire length of its coils. This lamina together with the cochlear duct divides the cavity of the cochlea into **two sections**: **the scala vestibuli** which communicates with the vestibule and **the scala tympani** which opens on the skeletized bone into the tympanic cavity through **the fenestra cochlea**. Near this fenestra in the scala tympani is a very small inner orifice of the aqueduct of the cochlea (**aqueductus cochleae**), whose external opening (apertura externs canaliculi cochleae) lies on the inferior surface of the pyramid of the temporal bone.

The **membranous labyrinth** (labirynthus membranaceus) lies inside the bony labyrinth and repeats its configurations more or less exactly. It contains the peripheral parts of the statokinetic and auditory analysers. Its walls are formed of a thin semitransparent connective tissue membrane. The membranous labyrinth is filled with a transparent fluid called the **endolymph**. Since the membranous labyrinth is somewhat smaller than the bony labyrinth, a space is left between the walls of the two; this is the perilymphatic space (spat ium perilymphaticum) filled with **perilymph**. Two parts of the membranous labyrinth are located in the vestibule of the bony labyrinth: **the utricle** (utriculus) and the **saccule** (sacculus).

The utricle has the shape of a closed tube and occupies the elliptic recess of the vestibule and communicates posteriorly with **three membranous semicircular ducts** (ductus semicirculares) which lie in the same kind of bony canals exactly repeating their shape. This it why it is necessary to distinguish the **anterior, posterior and lateral membranous ducts** (ductus semicircularis anterior, posterior and lateralis) with their corresponding ampulles: ampulla membranacea anterior, posterior and lateralis.

The saccule, a pear-shaped sac, lies in the spherical recess of the vestibule and is joined with the utricle and with the long narrow endolymphatic duct which passes through the aqueduct of the vestibule and ends as a small blind dilatation termed the **endolymphatic sac** (saccus endolymphaticus) under the dura mater on the posterior surface of the pyramid of the temporal bone. The small canal joining the endolymphatic duct with the utricle and saccule is called the **utricosaccular duct** (ductus utriculosaccularis). With its narrowed lower end which is continuous with the narrow **ductus reuniens**, the saccule joins with the vestibular end of the **duct of the cochlea**. Both vestibular saccules are surrounded by the perilymphatic space.

In the region of the semicircular canals the membranous labyrinth is suspended on the compact wall of the bony labyrinth by a complex system of threads and membranes. This prevents its displacement during forceful movements.

Neither the perilymphatic nor the endolymphatic spaces are sealed off completely from the environment. The perilymphatic space communicates with the middle ear via the fenestra vestibuli and the fenestra cochleae which are both elastic and yielding. The endolymphatic space is connected by means of the endolymphatic duct with the endolymphatic sac lying in the cranial cavity; it is a more elastic reservoir which communicates with the inner space of the semicircular canals and the rest of the labyrinth. This creates physical prerequisites for the response of the semicircular canals to progressive movement.

Structure of the auditory analyser

The anterior part of the membranous labyrinth, **the duct of the cochlea**, (ductus cochlearis), enclosed in the bony cochlea, is the most vital component of the organ of hearing. The duct of the cochlea begins with a blind end in the cochlear recess of the vestibule somewhat posteriorly of **the ductus reuniens** that connects the duct with the saccule. Then it passes along the entire spiral canal of the bony cochlea and ends blindly at its apex. On cross section the duct of the cochlea **is triangular in shape**. One of its three walls is fused with **the external wall** of the bony canal of the cochlea; another wall, termed the **spiral membrane** (membrana spiralis), is a continuation of the osseous spiral lamina which stretches between the free edge of the latter and the outer wall. **The third**, a very thin wall of the **duct of the cochlea** (paries vestibularis ductus cochlearis) stretches obliquely from the spiral lamina to the outer wall. The **basilar membrane** (membrana spiralis) encloses the basilar lamina which carries the apparatus appreciating sounds: the organ of Corti, or the spiral organ. The duct of the cochlea separates the scala vestibuli from the scala tympani except for a place in the dome of the cochlea where they communicate through an opening called **helicotrema**. Scala vestibuli communicates with the perilymphatic space of the vestibule and scala tympani ends blindly at the fenestra cochlea.

The organ of Corti, or **the spiral organ** (organum spirale) is located along the length of **the duct of the cochlea** on the basilar lamina occupying the part nearest to the osseous spiral lamina. The **basilar lamina** (lamina basilaris) consists of a large number (24000) of fibrous fibres of different length tightened like strings (**acoustic strings**). According to the well-known theory of Helmholtz, they are resonators, the vibrations of which make it possible to appreciate tones of different pitch. According to the findings of electron microscopy, however, these fibres form an elastic network which as a whole resonates with strictly graded vibrations. The organ of Corti itself is composed of several rows of epithelial cells among which the neurosensory acoustic hair cells can be distinguished. Certain authors claim that this organ performs the role of a "reverse microphone" converting mechanical (acoustic) vibrations into electric oscillations.

The pathways of sound conduction

From the functional viewpoint, the organ of hearing (the peripheral part of the auditory analyser) is divided into two: (1) the sound-conducting apparatus, i.e. the external and middle ear, as well as certain components of the internal ear (peri- and endolymph); and (2) the sound-appreciating apparatus, i.e. the internal ear (schematical representation of the auditory analyser. The air waves collected by the ear pass into the external auditory meatus, hit the tympanic membrane and cause it to vibrate. The vibrations of the tympanic membrane, the degree of tension of which is regulated by the contraction of the tensor tympani muscle (innervation from the trigeminal nerve) move the handle of the malleus fused with the membrane. The malleus moves the incus, and the incus moves the stapes fitted in the fenestra vestibuli leading into the internal ear. The displacement of the stapes in the fenestra vestibuli is regulated by the contraction of the stapedius muscle (innervation by the nerve supplied to it from the facial nerve). Thus, the chain of ossicles which are linked in mobility, conducts the vibrating movements of the tympanic membrane in a definite direction, namely, to the fenestra vestibuli.

The movement of the stapes in the fenestra vestibuli stirs the labyrinth fluid which protrudes the membrane of the vestibuli cochlea to the exterior. These fluid movements are necessary for the functioning of the highly sensitive elements of the organ of Corti. The first to move is the perilymph in the vestibule. Its vibrations in the perilymph of scala vestibuli reach the apex of the cochlea and are conducted via the helicotrema to the perilymph in the scala tympani; then they descend along it to the secondary tympanic membrane and close the fenestra cochleae (which is a vulnerable place in the osseous wall of the internal ear) and return, as it were, to the tympanic cavity. From the perilymph the sound vibrations are conducted to the endolymph and through it to the organ of Corti. Thus, due to the system of the auditory ossicles of the tympanic cavity, the vibrations of air in the external and internal ear are converted into vibrations of the fluid in the membranous labyrinth which stimulate the special acoustic hair cells of the organ of Corti comprising the receptor of the auditory analyser.

In the receptor, which plays the role of a "reverse microphone" the mechanc vibrations causing fluctuations in the fluid (endolymph) are converted into electric oscillations characterizing the nerve process spreading along the conductor to the cerebral cortex. The conductor of the auditory analyser is made up of auditory conductors consisting of a number of links. The cellular body of **the first neuron** lies in **the spiral ganglion**. The peripheral process of the bipolar cells enters the organ of Corti and ends at the receptor cells, while the central process passes as the cochlear division of the auditory nerve to its nuclei, **nucleus dorsalis and nucleus ventralis**, located in **the rhomboid fossa (pons)**. According to the electrophysiological data, different parts of the auditory nerve conduct sounds of various frequency of vibration.

The nuclei mentioned above contain the bodies of the secondary neurons, the axons of which form the central acoustic fasciculus, which, in the region of the posterior nucleus of **the trapezoid body**, crosses with the fasciculae of the same name on the opposite side, forming **the lateral lemniscus**. The fibres of the central acoustic fasciculus coming from the ventral nucleus form a trapezoid body and, on passing the pons, become part of the lateral lemniscus of the opposite side. The fibres of the central fasciculus coming out of the dorsal nucleus, run along the floor of the fourth ventricle in the form of **auditory striae** (striae medullares ventriculi quarti), penetrate the reticular formation of the pons and, together with the fibres of the trapezoid body, become part of the lateral lemniscus on the opposite side. **The lateral lemniscus** ends partly in **the inferior quadrigeminal bodies** of the tecta1 lamina and partly in **medial geniculate body** (meta-thalamus), where **the third neurons** are located.

The inferior quadrigeminal bodies serve as the reflex centre for auditory impulses. They are connected with the spinal cord by **the tectospinal tract** through which motor responses to auditory stimuli entering the mesencephalon are made (startreflex). Reflex responses to auditory impulses may also be received from other intermediate auditory nuclei, namely nuclei of the trapezoid body and lateral lemniscus, connected by short pathways with the motor nuclei of the mesencephalon, the pons and medulla oblongata.

Ending in structures related to hearing (the inferior quadrigeminal bodies and the medial geniculate body) the auditory fibres and their colleterals also join **the medial longitudinal fasciculus** by means of which they establish connections with **the nuclei of the oculomotor muscles** (CN 3, 4 and 6) and **the motor nuclei of other cranial and spinal nerves**. These connections provide an explanation for the reflex responses to auditory stimuli.

The inferior quadrigeminal bodies have no centripetal connections with the cortex. The medial geniculate body contains the cellular bodies of the last neurons whose axons as part of the internal capsule reach the cortex of **the temporal lobe** of the brain by **radiatio acustica. The cortical end** of the auditory analyser is located in the **superior temporal gyrus** (Heschl's gyrus, area 41). Here the vibrations of air in the external ear causing movement of the auditory ossicles in the middle ear and fluctuation of fluid in the internal ear are converted into nerve impulses further in the receptor, transmitted along the conductor to the brain cortex, and perceived in the form of auditory sensations.

Owing to the auditory analyser, various sound stimuli received in our brain as sound perceptions and complexes of perceptions, sensations, become signals (**primary signals**) of vitally important environmental phenomena.

The organ of gravitation and balance

The analyser of gravitation, or the statokinetic analyser begins in the membranous labyrinth, where its peripheral part is located. The parts of the membranous labyrinth (discussed in describing the auditory analyser) are related to the statokinetic analyser, or the analyser of gravitation.

The structure of the statokinetic analyser (the **analyser of gravitation**).

The sensory hair cells which the fibres of the vestibular part of the auditory nerve approach from the exterior are located in a layer of squamous epithelium lining the inner surface of the **saccule, utricle and the ampullae** of the semicircular canals. In the utricle and saccule these sites appear as whitish **spots** (**maculae** of **the utricle and saccule**) (**s. maculae staticae**), because the sensitive epithelium in them is covered by a jelly-like substance. In **the ampullae of the semicircular canals** they appear in the form of **cristae** (cristae ampullares, s. cristae staticae). The epithelium covering the projections of the cristae has sensory cells with pili, which are joined by nerve fibres. The semicircular canals as well as the saccule and utricle may also be stimulated by either acceleration or deceleration of rotary or right-angle movements, by shaking, swinging or any kind of change in the position of the head, as well as by the force of gravity. The stimulus in such instances is tension of sensory hairs or the pressure exerted on them by the jelly-like substance, which stimulates the nerve endings.

Thus, the vestibular apparatus and the entire system of conductors connected with it and reaching the cerebral cortex, is the analyser of the position and movements of the head in space. As a consequence of this, it was named **the statokinetic analyser**. The receptor of this analyser in the form of special hair cells which are stimulated by the flow of endolymph is located in **the utricle and saccule (maculae**), which regulate **static equilibrium**, i.e. the balance of the head and, thereby, the body when it is at rest, and in the ampullae of the **semicircular canals (cristae**), regulating **dynamic equilibrium**, i.e. the balance of the body moving in space. Although changes in the position and movements of the head are also regulated by other analysers (particularly by the visual, motor and skin analysers), the vestibular analyser plays a very special role.

The pathways of the statokinetic analyser

The first neuron of the reflex arc of the statokinetic analyser lies in **the vestibular ganglion**. The peripheral processes of the cells of this ganglion advance as part of the **vestibular division** of **the auditory nerve** to the labyrinth and communicate with the receptor. Meanwhile, the central processes pass together with the cochlear division of the auditory nerve through **the porus acusticus internus** into the cranial cavity and further into the brain matter through **the cerebellopontile angle**. Here the fibres of the first neuron divide into ascending and descending fibres and approach **the vestibular nuclei (second neuron**), which are situated in the medulla oblongata and pons on the floor of the rhomboid fossa. On each side there are four vestibular nuclei: **superior, lateral, medial** and **inferior**. The ascending fibres end in the superior nucleus, the descending fibres in the remaining three nuclei. The descending fibres and their accompanying nucleus descend very low, through the whole medulla oblongata to the level of the gracile and cuneate nuclei.

The vestibular nuclei give rise to fibres running **in three directions**:

(1) to the cerebellum;

(2) to the spinal cord, and

(3) the fibres which are part of the medial longitudinal fasciculus.

The fibres **to the cerebellum** pass through its inferior peduncle; this path is called **the vestibulocerebellar tract**. (Some of the fibres of the vestibular nerve without interruption in the vestibular nuclei pass directly into the cerebellum; the vestibular nerve is connected with the flocculonodular lobe, the oldest part of the cerebellum.)

There are also fibres running in the opposite direction, from the cerebellum to the vestibular nuclei; as a result, a close connection is established between them, while the nucleus fastigii of the cerebellum becomes an important vestibular centre.

The nuclei of the vestibular nerve are connected with **the spinal cord** through the **vestibule-spinal tract** (extrapyramidal system). It passes in **the anterior funiculi** of the spinal cord and approaches the cells of the anterior horns along the entire length of the spinal cord. It is the connections with the spinal cord that are responsible for the conduction of the vestibular reflexes to the muscles of the neck, trunk and limbs, and for the regulation of the muscle tonus.

The fibers from the vestibular nuclei, comprising part of **the medial longitudinal** fasciculus, establish contact with the nuclei of the nerves of the eye muscles. As a result vestibular reflexes are accomplished by the eye muscles (compensating for accommodation of the eyes, i.e. keeping them directed at a certain object when the head is moved). This also explains the peculiar movements of the eyeballs (**nystagmus**) in loss of balance.

The vestibular nuclei are connected through the reticular formation with the nuclei of **the vagus and glossopharyngeal nerves**. This is why dizziness in stimulation of the vestibular apparatus is often attended by a vegetative reaction in the form of a slower pulse beat, a drop in arterial pressure, nausea, vomiting, cold hands and feet, a pale face, cold sweat, etc.

Vestibular tracts play a major role in regulating balance and help keep the head in its natural position even when the eyes are closed.

A decussated tract is directed from the vestibular nuclei to the thalamus (**third neuron**) and further to the cerebral cortex for conscious awareness of the head's position. It is presumed that **the cortical end** of the statokinetic analyzer is distributed in the cortex of **the occipital and temporal lobe**s.

The organ of taste

The importance of the sense of taste consist in recognizing the qualities of food. Formations like **taste buds** described below already existed in fish, although at this period they were as yet not fully differentiated from the organ of skin sense. Beginning with amphibians such buds were already concentrated in the oral cavity and nasal cavity, thus performing the function of taste buds. In reptiles and mammals the localization of taste buds is even more limited. They are mainly located on the tongue, although are also encountered on the palate, its arches and epiglottis. In man most of the taste buds are located in **the vallate and foliate papillae** (papillae vallatae et foliatae), a much less number in the **fungiform papillae** (papillae fungiformis), and finally some of them occurs on **the soft palate**, on the **posterior surface of the epiglottis** and on the **medial surface of the arytenoids cartilages**. The buds hold the taste cells which constitute the receptor of the taste analyzer. Its conductor is comprised of the conducting tracts from the receptors of taste consisting of **three paths**.

The first neuron is contained in ganglia of the afferent nerves of the tongue. The nerves conducting the sense of taste in man are**: 1) the chorda tympani of the facial nerve** (the first two thirds of the tongue**), 2) the glossopharyngeal nerve** (the posterior third of the tongue, the soft palate and its arches), and **3) the vagus nerve** (epiglottis).

The location of the firth neuron: 1) **the ganglion of the facial nerve** (**ganglion geniculi**). The peripheral processes of the cells of the this ganglion run as a part of the chorda tympany to **the anterior two thirds** of the tongue mucosa where they come into contact with the taste receptor. The central processes pass as part of the sensory root of the facial nerve (n. intermedius) into the medulla oblongata. 2) **the inferior ganglion of the the glossopharyngeal nerve**. The peripheral fibers of the cells of this ganglion run as part of ninth cranial nerve to the mucosal coat of **the last third** of the tongue, where they come into contact with the receptors. The central processes pas as part of this nerve into the pons. 3) the **inferior ganglion of the the vagus nerve**. As a part of the superior laryngeal nerve the peripheral processes of the cells of this ganglion approach the receptors located in **the epiglottis.** The central processes, as part of the vagus nerve, pas to the medulla oblongata. All the mentioned taste fibers end in medulla oblongata and pons, in the nucleus of **tractus solitaries (second neuron)**. The processes of these last neurons ascend to the thalamus, that commute with cortical terminal point of analyzing of taste plased in **prahippocampal gyrus**, Ammon corn (**hippocampus**) and **uncus**, of temporal lobe.

The organ of smell

The receptor of smell analyzer is represented by the olfactory sells that are spreads **in olfactory area** of the nasal mucosa. The axons of olfactory sells as component of fila olfactoria pass through the sieve of cribriform plate of ethmoid bone. Olfactory bulb takes over these axons connecting them with mitral sells (**second neuron**) making **the olfactory glomeruli.** In continuation the axons of mitral neurons will run to the base of olfactory tract, the olfactory triangle, where its terminate in the grey matter of the anterior perforate substance and pelucide septum. **The cortical analyzer** is the same located as in organ of taste in **prahippocampal gyrus**, Ammon corn (**hippocampus**) and **uncus**, of temporal lobe. There is direct way from olfactory triangle to the cortical end and using **cingulate gyrus** (cingulum, isthmus gyri cinguli, parahippocampal gyrus), mamilary bodies and fornix. **Thalamus** (anterior nuclei) also is connected with mamilar body (by mamilothalamic tract – Vicq d'Azyr), taking part in subcortical analyzing of smell. At the level of hypothalamus (**tuber cinereum**) olfactory information is related with visceral sensation, including gustatory.

The skin

(Organs of the senses of touch, temperature and pain)

The skin (cutis) forms the general covering of the body protecting the organism from external influences. It is an important organ of the body performing several major functions: thermoregulation, the secretion of sweat and sebum and together with them harmful substances, as well as respiration (gas exchange); it is also a depot of energy resources. It is presumed to have incretory properties. The principal function of the skin consists in the reception of a wide variety of stimuli produced by the natural environment (tactile, pressure, temperature, and harmful stimulations). The skin is thus a complex accumulation of receptors found over a wide receptive area reaching up to 1.6 m2 in adults.

The structure of the skin is discussed in detail in the course of histology so we shall limit ourselves to a brief review of its macroscopic structure.

The skin of man, as that of all vertebrates, consists of two layers.

1. The surface layer of the skin, **the epidermis**, develops from the ectoderm and is a flat stratified keratinized epithelium, the outer layers of which keratinize and gradually desquamate. As a result of tight shoes or inadequate working tools callosities appear, which are local thickenings of the cornified layer.

2. **The deep layer**, the skin proper, **corium**, **dermis** develops from the mesoderm and is built of fibrous connective tissue with an admixture of elastic fibres (on which the elasticity of the skin depends, particularly at a young age) and smooth muscle fibres. The smooth fibres are arranged either as bundles forming the muscles of hair or gathered in layers (papilla, areola papillaris, skin of the penis, perineum), forming (as is the case in the scrotum) a muscular coat (tunica dartos). On the face the corium is intimately connected with the striated muscles of expression.

The superior dense layer of the dermis presses into the epidermis in the form of small papillae (**papillae cutis**) which contain blood and lymph capillaries and end nerve corpuscles. The papillae protrude on the surface of the skin as a result of which ridges (**cristae cutis)** and grooves (**sulci cutis**) form. The cristae cutis have orifices for the sweat glands from which drops of sweat flow into the sulci thus moistening all the surface of the skin. On the palm of the hand and the sole of the foot the cristae and sulci form an intricate pattern **of very special configuration for every individual human being**. This proves useful in anthropology and in forensic medicine for establishing the identity of a person, if his or her fingerprints had been recorded earlier by **dactyloscopy**.

A delicate pattern of triangular and rhombic areas is noticeable on the rest of the skin surface. Shafts of hair arise from the angles of the rhombi and triangles and sebaceous glands open there, while the sweat glands open on areas above the surface. In some places there are large folds of skin (on the extensor surface of joints, on the palm and scrotum, the wrinkles of the face, etc.) resulting from frequent stretching of skin and the subsequent weakening of its elasticity.

The inferior layer (**hypodermis**) of the corium is continuous with the subcutaneous tissue (tela subcutanea) which consists of loose connective tissue containing accumulations of fatty cells (subcutaneous adipose layer) and covers the deeper lying organs. The fatty tissue plays a part in thermoregulation. It is a poor conductor of heat and therefore particularly well developed in polar animals. Corpulent persons also suffer less from cold than lean individuals. The degree to which the subcutaneous adipose layer is developed depends on the sex, age and the constitution of the individual; it reflects the level of metabolism, as a result of which a person may gain or lose weight in his lifetime. The mechanical factor is also significant. In those parts of the body which experience constant pressure in standing (**the soles of the feet**) and in sitting (**buttocks**). The subcutaneous adipose layer is developed more than in the other areas to create a kind of elastic cushion. Owing to the local development of fat on the flexor part of the foot and hand, soft tactile elevations (**toruli tactiles**) form similar to such pads in animals; they are particularly developed in man in intrauterine life.

The colour of the skin depends mainly on the pigment (**melanin**) located in the deepest layer of the epidermis. There is very much pigment in the skin of coloured races. In blacks it is deposited not only in and between the cells of the entire Malpighian layer, but in the cells of the upper layer of the corium. The colour of the skin of modern man varies fairly widely. Between the northern European with his white-pink skin and the skin of a black there are numerous colour transitions.

The hair (pilus) has a part which is implanted in the skin, a root, and a part projecting freely over the skin, the shaft. The colour of hair depends on the pigment as well as on the content of air in the hair. When the amount of air in the hair increases with the simultaneous disappearance of pigment, the hair turns grey.

The hair is a poor conductor of heat and prevents the loss of heat by the body, which explains the considerable development of hair as fur in mammals. Man is the only primate whose body is not entirely covered with hair, the absence of which is evidently connected with the wearing of clothes (artificial covering).

The nails (ungues) like hair, are a horny formation, derived from the epidermis. The claws of predators, the hooves of ungulate animals and nails of primates are homologous adaptations at the end phalanges which developed to perform the digital functions of these animals. The plate of the nail which derives from the epidermis lies on a connective-tissue **unguis bed** from where the nail grows: the bed of the nail is therefore called **the matrix (womb) unguis**.

Three types of glands are distinguished in the skin according to the character of secretion: (1) *sebaceous*, (2) **sweat** and (3) **mammary glands**.

Vessels and nerves. The arteries of the skin arise from the deep large trunks passing close to the skin, or from muscle arteries. Considerable accumulations of skin vessels are seen near sensory organs, around the natural orifices of the face and the tactile elevations of the hand.

As a sensory organ the skin is richly supplied with sensory nerve endings connected with the nerve fibres which are part of the skin branches of the cranial and spinal nerves. The skin is rich in tactile receptors which are mainly developed in the palm, the tactile elevations of the fingertips, a fact connected with the function of the hand as an organ of labour. The sympathetic fibres innervating the glands, vessels and smooth muscles are a component of the animal nerves which reach the skin.

The conducting tracts of the skin analyser

The afferent fibres of the skin analyser bring to the cerebral cortex tactile stimuli and the sense of stereognosis, pain, and thermal stimulations.

The conducting tracts of skin tactile sense (the sense of touch)

The ganglio-spino-thalamo-cortical tract. The receptor is in the skin. The conductor consists of three neurons. The cell body of **the first neuron** is **in the spinal ganglion** which is an aggregation of cells of the peripheral neurons concerned with all types of sensitivity. The process arising from the cells of this ganglion divides into two branches, the peripheral one runs in the skin nerve to the receptor, while the central branch passes as a component of the posterior root into the posterior funiculi of the spinal cord and, in turn, separates there into an ascending and descending branches. The terminal ramifications and collaterals of some of the fibres end in the posterior horns of the spinal cord in the substantia gelatinosa (this part of the tract is called the gangliospinal tract [tractus gangliospinalis1). The other ascending fibres do not enter the posterior horns but pass in the posterior funiculi and then in the fasciculus gracilis and fasciculus cuneatus to reach the nucleus gracilis and nucleus cuneatus in the medulla oblongata (this part of the tract is the gangliobulbar tract Itractus gangliobulbaris]).

The cell body of **the second neuron** is in **the posterior horns** of the spinal cord and in the above-named nuclei of **the medulla oblongata**. The axons of cells lodged in the posterior horns cross the midplane in the white commissure to become a component of the anterior spinothalamic tract stretching in the lateral funiculus of the opposite.

It must be borne in mind that the fibres of the spinothalamic fasciculi cross not at the level of the entry of the corresponding posterior root into the spinal cord but higher by two or three segments. This is of essential importance in clinical practice because in unilateral injury to this fasciculus the disorders of skin sense on the contralateral side occur not on the level of the injury but below it.

This fasciculus reaches the thalamus through the brain stem. On the way it establishes connections with the motor nuclei of the brain stem and the cranial nerves along which head reflexes occur in stimulation of the skin, e.g. movements of the eye in stimulation of the skin on the hand. The axons of the second link cells situated in the nuclei of the medulla oblongata also reach the thalamus along the bulbothalamic tract (tractus bulbothalamicus) which crosses to the opposite side in the medulla oblongata to form the sensory decussation (decussatio lemniscorum). Therefore, for each half of the body the spinal cord contains two tracts, as it were, conveying impulses of touch, namely: (1) uncrossed, in the posterior funiculus of the same side and (2) crossed, in the lateral funiculus of the opposite side. That is why in unilateral lesion of the spinal cord tactile sense may be undisturbed because the corresponding fasciculus on the healthy side remains intact.

The cell body of **the third neuron** is in the thalamus. The axons of the cell extend in the thalamocortical tract to the cerebral cortex **into the postcentral gyrus** (areas 1, 2, and 3) and the superior parietal lobule (areas 5 and 7), where the cortical end of the skin analyser is situate).

The sense of pain and the sense of touch are marked by diffuse localization in the cerebral cortex, which explains their milder disorders in local cortical lesions.

The conducting tracts of three-dimensional skin sense, stereognosis (the recognition of objects by touch)

Skin sense, like tactile sense conveyed along the fasciculus gracilis and fasciculus cuneatus, has three links: (1) **the spinal ganglia**; (2) the **nucleus gracilis and nucleus cuneatus** in the medulla oblongata; (3) the thalamus and, finally, the skin analyser nucleus in the **superior parietal lobule** (areas 5 and 7).

The Conducting Tracts of Pain and Temperature Sense

The cell body of **the first neuron** is in the **spinal ganglion** whose cells are connected by peripheral processes with the skin and by central processes with the posterior horns of the spinal cord (**nuclei propria**) in which the cell body of the second neuron (gangliospinal tract) is situated. The axon of the second neuron passes to the opposite side as a component of the white commissure and ascends in **the lateral spinothalamic tract** to the **thalamus**. It should be pointed out that this tract separates, in turn, into two parts: an anterior part conducting the sense of pain, and a posterior part conveying temperature sense. The thalamus contains the cell body of the third neuron whose process extends in the thalamocortical tract to the brain cortex and terminates in **the postcentral gyrus** (the cortical end of the skin analyser).

Some authors believe that the sense of pain is appreciated not only in the cortex but also in the thalamus in which all types of sense acquire an emotional colouring. Pain and temperature impulses from the parts or organs of the head are conveyed by the corresponding cranial nerves (fifth, seventh, ninth, and tenths pairs).

Since the fibres of the second neuron of the conducting pathways extending from the exteroceptors cross to the other side, the impulses of pain, temperature and partly those of tactile sense are brought to the postcentral gyrus from the opposite side. It should therefore be borne in mind that affection of the first or second neuron before (below) the level of the crossing causes sense disorders on the side of the affection. Pain and temperature sense is disturbed on the side contralateral to the affection when damage occurs to the second neuron above the crossing or if the third neuron is damaged.

The mammary glands

The mammary glands (mammae) are characteristic adaptations for feeding newborns in mammals, whence they received their name. The mammary glands derive from the **sweat glands**. Their number depends mainly on -the number of offspring that are born. Monkeys and man possess one pair of glands located on the chest. That is why these glands are also often commonly referred to simply as breasts. In males the mammary gland remains in its rudimentary form throughout lifetime. In females it grows and increases in size from the attainment of puberty. The mammary gland achieves the peak of development toward the end of pregnancy, although milk is produced (lactation) in the postnatal period.

The mammary gland is located on the fascia of the pectoralis major muscle with which it is connected by loose connective tissue providing for its mobility. The base of the gland extends from the third to the sixth rib reaching the sternal border, medially. Slightly downward from the middle of the gland on its anterior surface is **a nipple** (papilla mammae) the top of which is rutted by the milk grooves opening in it and surrounded by a pigmented skin area, a peripapillary ring called areola of the breast (**areola mammae**). The skin of the peripapillary ring is wrinkled because of the big areolar glands (**glandulae areolares**) contained in it; between these glands are also large sebaceous glands. The skin of the peripapillary circle and the nipple also contains numerous smooth muscle fibres which partly encircle the nipple and partly run lengthwise: when they contract, the nipple grows tense and this makes sucking easier.

The gland itself consists of 15 to 20 separate cone-like lobules **- lobules of the mammary gland** (lobuli glandulae mammariae) which are arranged radially with their apic directed toward the nipple. In structure, the mammary gland belongs to the type of complex alveolar-tubular glands. All the ducts of one big lobe unite to form **the lactiferous duct** (ductus lactiferi) which is directed toward the nipple and ends at its summit as a small funnel-like opening.

Vessels and nerves. The arteries arise from the **posterior intercostal arteries**, **internal thoracic artery** and from **the lateral thoracic artery**. Some of the veins attend these arteries, others pass under the skin forming a network of wide loops, which is partly visible through the skin in a pattern of thin blue lines. The lymphatic vessels are of great practical interest because the mammary gland is often afflicted with cancer, which spreads along these vessels.

The gland receives its sensory nerves from the second to fifth intercostal nerves. Branches from nn. pectorales medialis and lateralis from the brachial plexus and nn. supraclaviculares from the cervical plexus also take part in the innervation of the skin covering the gland. The sympathetic nerves also penetrate the gland together with the vessels.

The interoceptive analyser

The interoceptive analyser, in contrast to other analysers, does not possess a compact and morphologically strictly demarcated conducting pathway although it maintains its specificity along its entire distance.

Its receptors, termed interoceptors, are scattered in all organs of vegetative life (the viscera, vessels, smooth muscles and glands of the skin, etc.).

The conductor is formed of afferent fibres of **the vegetative nervous system** passing in **the sympathetic, parasympathetic**, and **animal nerves** and then in the spinal cord and brain to the cortex. Part of the conductor of the interoceptive analyser is formed by afferent fibres running in the cranial nerves (fifth, seventh, ninth, and tenth) and carrying impulses from the organs of vegetative life situated in the area innervated by each of these nerves. The afferent pathway formed by them consists of three links: the cells of the first link lie in the ganglia of these nerves (the trigeminal ganglion, ganglion of the facial nerve, and inferior ganglion of the glossopharyngeal nerve); the cells of the second neuron are in the nuclei of these nerves (the nucleus of the spinal tract of the trigeminal nerve, **nucleus of tractus solitarius** of the seventh, ninth, and tenth nerves). The fibres emerging from these nuclei cross to the opposite side and run to the thalamus. Finally, the cells of the third link are located in the thalamus.

The vagus nerve, which is the main component of parasympathetic innervation, makes up a considerable part of the interoceptive analyser conductor. The afferent pathway passing in it is also broken up into three links: the cells of the first neuron are in the inferior ganglion of the vagus nerve, those of the second neuron are in the nucleus of **tractus solitarius.**

The vagal fibres arising from this nucleus pass to the opposite side together with the processes of the second neurons of the glossopharyngeal nerve, intersect with the fibres of the other side, and ascend on the brain stem.

At the level of the superior quadrigeminal bodies they join the second neurons of the skin analyser (medial lemniscus) and reach the thalamus in which the cells of the third neurons are located. The processes of these cells pass through the posterior third of the posterior limb of the internal capsule to reach the lower part of the postcentral gyrus. A part of the cortical end of the interoceptive analyser connected with the cranial parasympathetic nerves and the area which they innervate is situated here.

Afferent pathways from the organs of vegetative life also run in the posterior roots of the spinal nerves. In this case the cells of the first neurons are in the spinal ganglia. **A powerful collector** of the afferent pathway extending from the organs of vegetative life passes through **the greater and lesser splanchnic nerves**. Different groups of splanchnic nerve fibres ascend in the spinal cord, in its posterior and lateral funiculi. The afferent fibres of the posterior funiculi convey interoceptive impulses which reach the cerebral cortex by way of the thalamus.

The afferent fibres of the lateral funiculi terminate in the nuclei of the brain stem, cerebellum, and thalamus (posterior ventral nucleus). Thus, the thalamus contains the cells of the third neurons of the entire conductor of the interoceptive analyser related both to sympathetic and to parasympathetic innervation. As a consequence closure of the interoceptive reflex arcs occurs in the thalamus and "outflow" to the efferent pathways is possible.

Closure of individual reflexes may take place also at other, lower levels. This explains the automatic, subconscious activity of organs controlled by the vegetative nervous system. **The cortical end** of the interoceptive analyser is located not **only in the postcentral gyrus but also in the premotor zone** where afferent fibres running from the thalamus terminate. Interoceptive impulses arriving along the splanchnic nerves also reach the cortex of the pre- and postcentral gyri in the zones of musculocutaneous sense.

These zones may possibly be the first cortical neurons of the vegetative nervous system efferent pathways concerned with cortical regulation of the vegetative functions. From this standpoint these first cortical neurons may be regarded as analogues of Betz's pyramidal cells which are the first neurons of the pyramidal tracts.

The limbic system consists of a set of structures situated on the medial surface of the cerebral hemispheres and the base of the brain. These are the gyrus cinguli, the amygdaloid nucleus (corpus amygdaloideum), the region of septum pellucidum, and the hippocampus.

The limbic system contributes to the maintenance of the equilibrium of the organism's internal environment (homeostasis) and regulation of **vegetative functions**. It is therefore also termed the “**visceral brain**”.

As is seen from what was said above the interoceptive analyser resembles the exteroceptive analysers structurally and functionally, but the area of its cortical end is much smaller than that of the cortical ends of the exteroceptive analysers. This explains its “coarseness”, i.e. less finer and less precise differentiations in relation to consciousness.

Intimate overlapping of the pathways and zones of representation of the animal and vegetative organs takes place at all levels of the central nervous system: in the spinal cord, cerebellum, thalami, and cerebral cortex. Visceral and somatic afferent impulses can be addressed to one and the same neuron “serving” both vegetative and somatic functions. All this ensures the cooperation of the animal and vegetative parts of the single nervous system. **The highest integration** of the animal and vegetative functions is accomplished in the cerebral cortex, especially in **the premotor zone**.

The reticular formation

Together with the conducting tracts from the organs of vision, hearing, taste, and olfaction they form the specific afferent system. In addition to this system, there is an afferent system represented by the reticular formation related to non-specific structures. The reticular formation appreciates absolutely all impulses - pain, light, sound, etc. The specific impulses from every organ of sense arrive along special conducting systems to the cortex of the corresponding analysers; in the reticular formation, in contrast, there is no specialization of neurons, one and the same neurons appreciate different impulses and transmit them to all layers of the cortex. The reticular formation constitutes, therefore, the second afferent system.

The reticular formation is a complex of structures situated in the central parts of the brain stem and distinguished by the following morphological features.

1. The neurons of the reticular formation differ from the other neurons in structure: their dendrites ramify poorly, while the axons, in contrast, separate into an ascending and descending branches which give off very many collaterals. As a result an axon can have contact with a great number of nerve cells (an axon 2 cm in length may communicate with 27 500 cells).
2. The nerve fibres extend in different directions and resemble on microscopy a network, on grounds of which Deiters (a hundred years ago) called it the reticular (L reticulum little net) formation.
3. The reticular formation consists of cells differing in size (giant, large, moderate-sized, and small) and shape (polygonal, spindle-shaped, spherical, oval). The macro-cell neurons of the reticular formation are so arranged that their dendrites and axon collaterals ramify in a plane perpendicular to the axis of the brain stem. The collaterals of the specific conducting tracts spread in the same direction. On grounds of this, some authors believe the reticular formation to be a series of neuropilic segments.
4. The dendrites of cells lying in the medial part of the reticular formation of the stem run longitudinally, those of cells in the lateral part run laterally, stretching toward the main sources of afferentation.
5. The cells of the reticular formation are at places scattered and at places form nuclei the discernment as the reticular nucleus of the tegmentum of the pons (nucleus reticularis tegmenti pontis). Ninety-six nuclei have been described to date.

The exact region of distribution of the reticular formation has not yet been determined. According to the physiological data, it is situated along the whole length of the brain stem and occupies the central position in the medulla oblongata, pons, midbrain, the sub- and hypothalamic areas, and even in the medial parts of the thalami. Here it tapers to end as a keel, the rostral end.

Connections of the reticular formation. The reticular formation is connected with all parts of the central nervous system and the following connections are therefore distinguished:

(1) **reticulopetal** connections passing:

a. from all afferent tracts of the brain stem;
b. from the cerebellum;
c. from the vegetative subcortical centres;
d. from the cortex of all cerebral lobes;

(2) **reticulofugal** connections passing:

a. to the cerebral cortex;
b. to the cranial nerve nuclei;
c. to the cerebellum;
d. to the spinal cord (the reticulospinal fasciculus in the medial part of the anterior column);

(3) **reticulo-reticular** connections (ascending and descending) between different nuclei of the reticular formation itself.

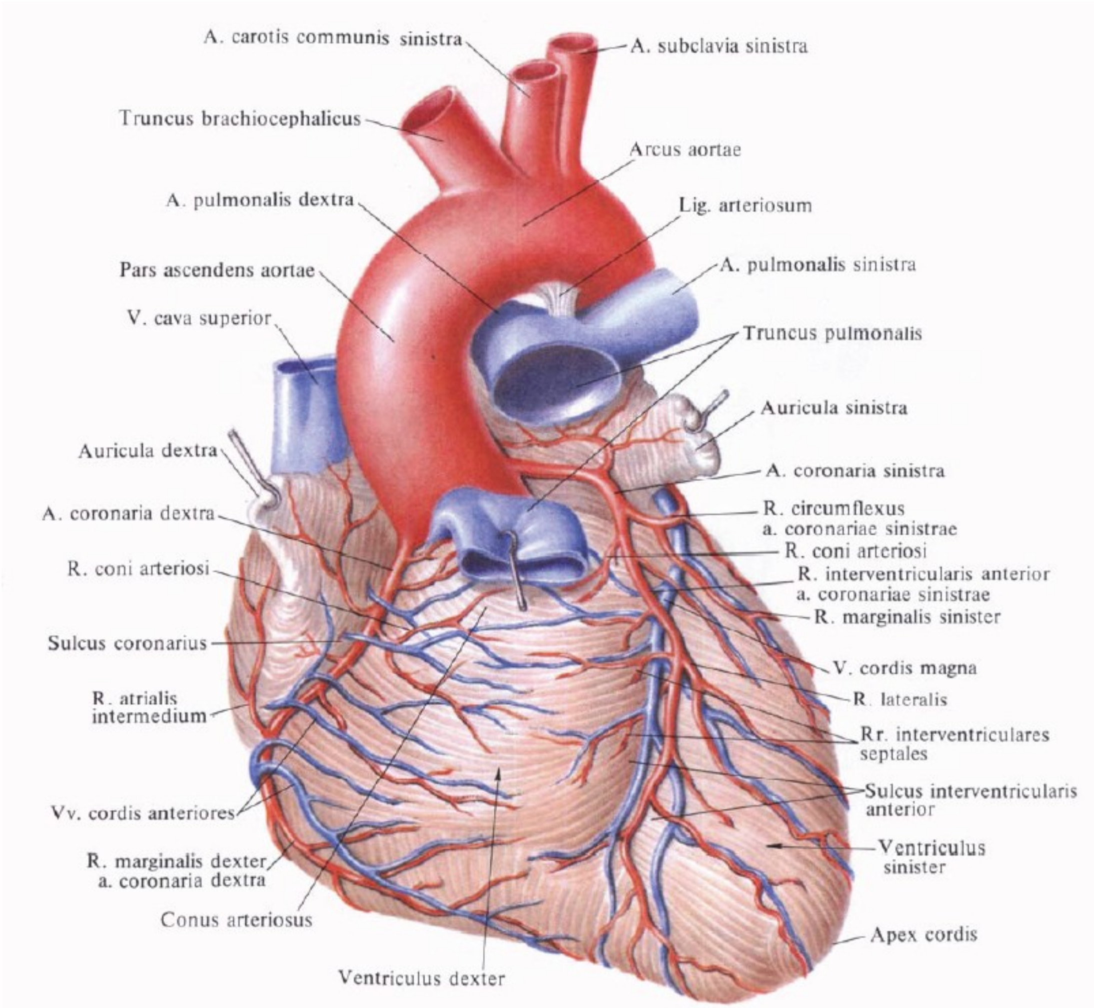
Function. Although the reticular formation was described in the 19th century (M. Lenhossék, 0. Deiters, V. Bechterew), attention was drawn to it only in the last decades when electrophysiological investigations led to the development of Sechenov's theory of central inhibition and demonstration of the inhibiting effect of the medulla oblongata.

It is now believed that the reticular formation is a “generator of energy” and that it regulates processes in other parts of the central nervous system, including the cerebral cortex. This function is ensured by the above mentioned two-way (reticulopetal and reticulofugal) connections of the reticular formation with the different parts of the brain and spinal cord. For instance, connection of the reticular formation cells with the cranial nerve nuclei provides for the switching of impulses from these cells in different directions as a result of which these nuclei take part in the accomplishment of many complex unconditioned-reflex acts. The reticular formation, therefore, coordinates all complex reflex acts in which many muscles participate in a variety of combinations (articulation, phonation, swallowing, respiration, as well as vomiting, coughing, etc.). In this event, the reticular formation itself is a complex reflex centre ensuring the relative maintenance of the automatism of respiration and cardiac activity. An especially important fact is that the reticular formation produces a generalized non-specific activating effect on **the entire cerebral cortex**; the conducting tracts ascending from the reticular formation to all the lobes of the brain are responsible for this. That is why it is termed also the ascending activating reticular system. Being connected by the collaterals of the axons of its cells with all specific afferent tracts passing through the brain stem, the reticular formation receives impulses from them and carries non-specific information to the cerebral cortex.

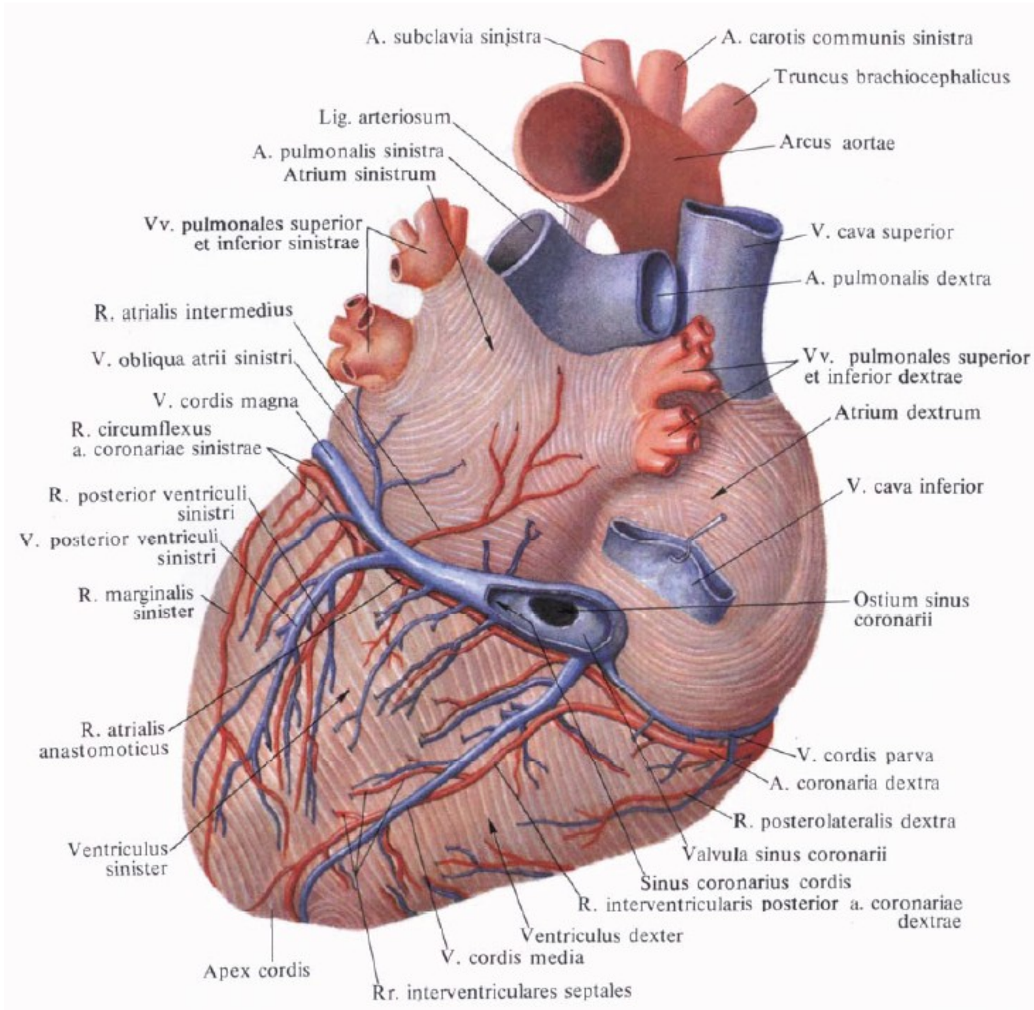
As a result two afferent systems pass through the brain stem to the cortex: one is specific and is composed of all specific sensory conducting pathways carrying impulses from all receptors (extero-, intero-, and proprioceptors) and terminating on the bodies of cells, predominantly those of the fourth cortical layer; the other, non-specific, system is formed by the reticular formation and terminates in the dendrites of all the cortical layers. The interaction of both these systems causes the final response of the cortical neurons.

The functional interrelationship between the reticular formation and the brain cortex is supplemented and mediated by **the system of humoral regulation**. Recent data provide evidence that the reticular formation cells themselves are hypersensitive to the effect of some humoral factors, to adrenaline in particular. The results of these studies indicate that the interrelationship between the reticular formation nuclei and the parts of the brain located at a higher level should be regarded today as a complex of neural and humoral connections responsible for the analysis and synthesis of nerve impulses reaching the cortex by way of the afferent tracts.

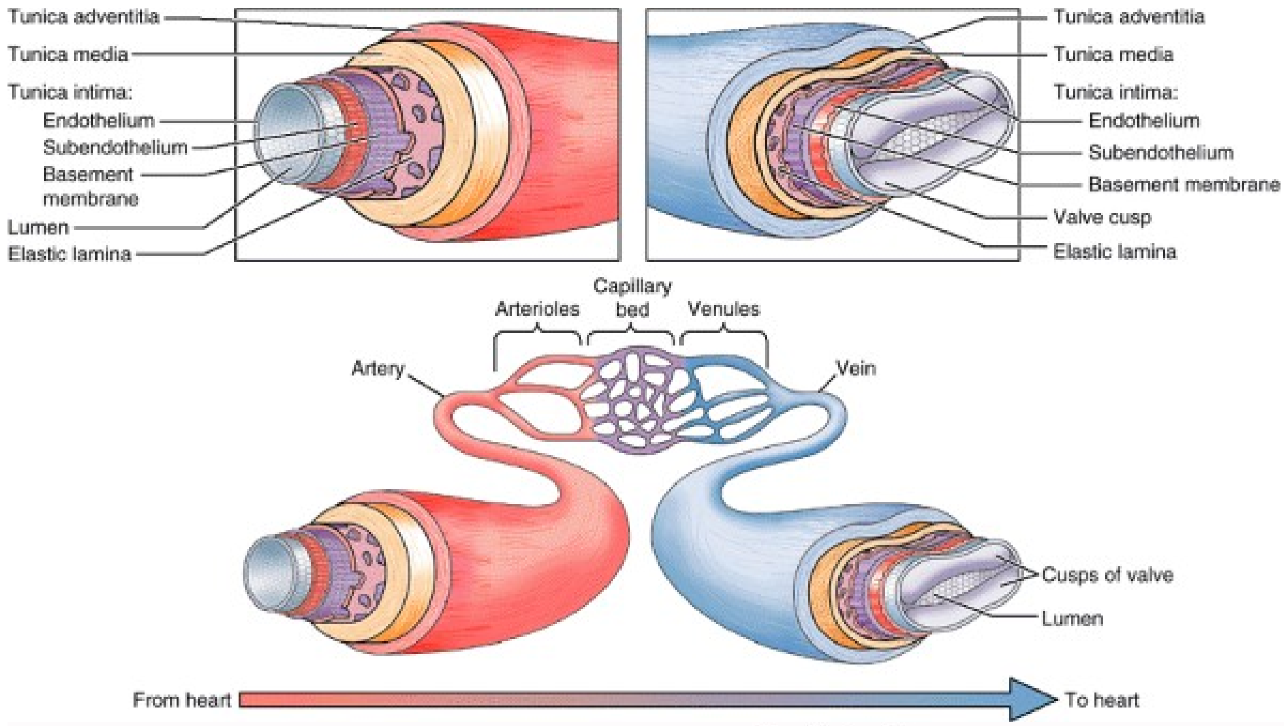
Appendix



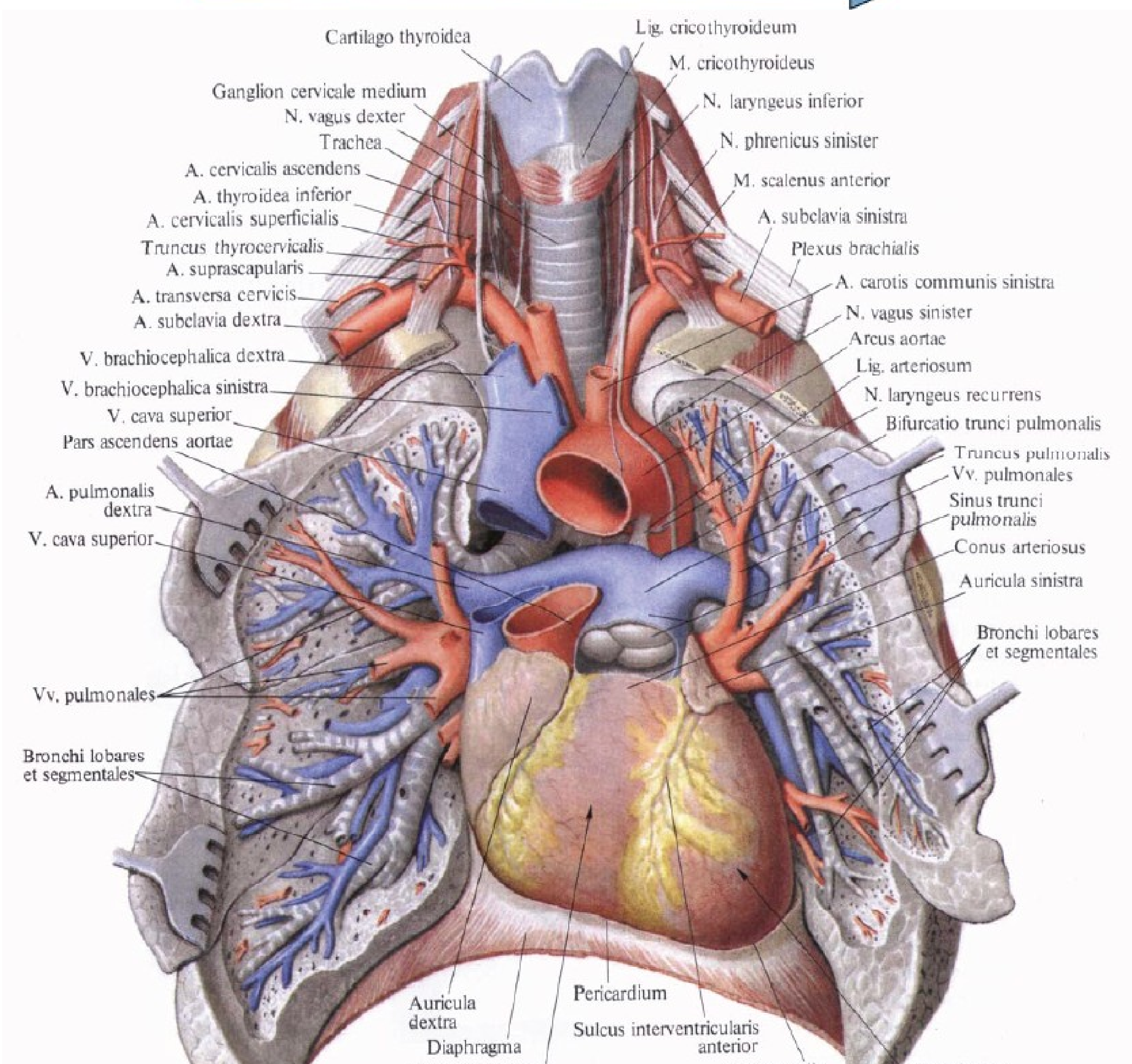
A. carotis communis sinistra
A. subclavia sinistra
Truncus brachiocephalicus
Arcus aortae
A. pulmonalis dextra
Lig. arteriosum
Pars ascendens aortae
A. pulmonalis sinistra
V. cava superior
Truncus pulmonalis
Auricula sinistra
Auricula dextra
A. coronaria sinistra
A. coronaria dextra
R. circumflexus
a. coronariae sinistrae
R. coni arteriosi
R. coni arteriosi
R. interventricularis anterior
a. coronariae sinistrae
R. marginalis sinister
Sulcus coronarius
V. cordis magna
R. atrialis
intermedium
R. lateralis
Rr. interventriculares
septales
Sulcus interventricularis
anterior
Vv. cordis anteriores
Ventriculus
sinister
R. marginalis dexter
a. coronaria dextra
Conus arteriosus
Apex cordis
Ventriculus dexter



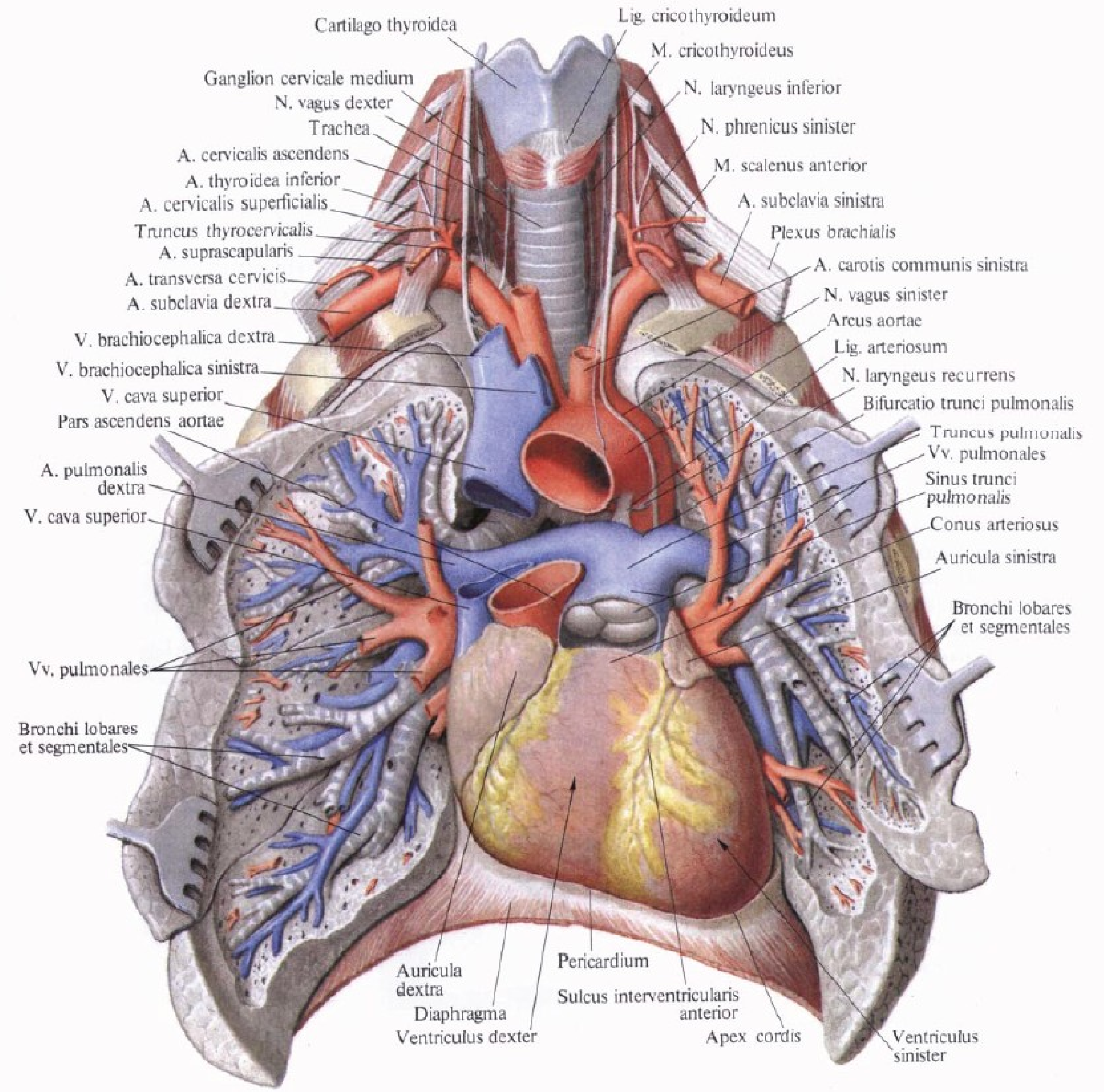
A. subclavia sinistra
A. carotis communis sinistra
Truncus brachiocephalicus
Lig. arteriosum
Arcus aortae
A. pulmonalis sinistra
Atrium sinistrum
Vv. pulmonales superior et inferior sinistrae
V. cava superior
A. pulmonalis dextra
R. atrialis intermedius
V. obliqua atrii sinistri
Vv. pulmonales superior et inferior dextrae
V. cordis magna
Atrium dextrum
R. circumflexus a. coronariae sinistrae
R. posterior ventriculi sinistri
V. cava inferior
V. posterior ventriculi sinistri
R. marginalis sinister
Ostium sinus coronarii
R. atrialis anastomoticus
V. cordis parva
A. coronaria dextra
R. posterolateralis dextra
Ventriculus sinister
Valvula sinus coronarii
Sinus coronarius cordis
R. interventricularis posterior a. coronariae dextrae
Ventriculus dexter
V. cordis media
Apex cordis
Rr. interventriculares septales



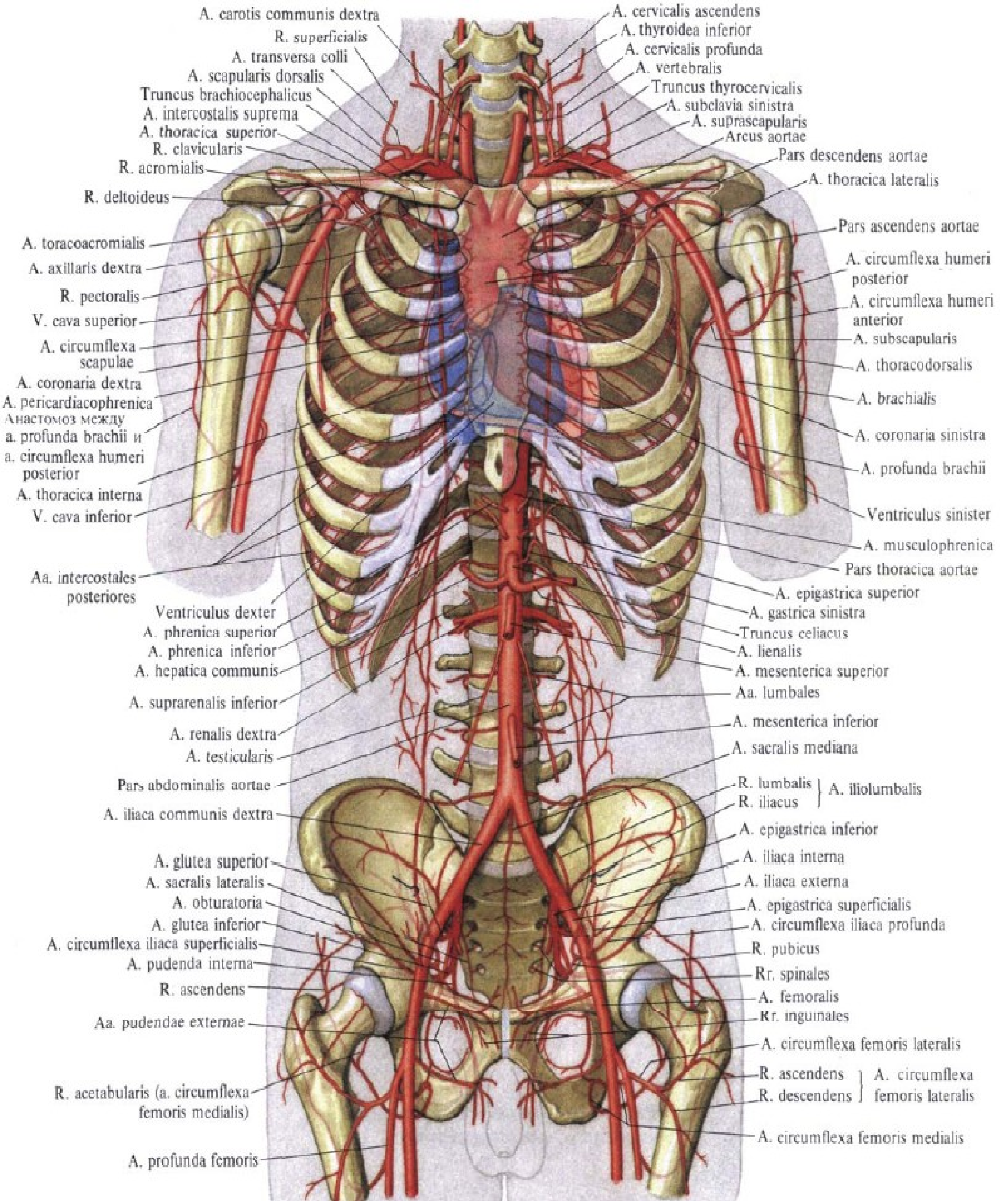
Tunica adventitia
Tunica media
Tunica intima:
Endothelium
Subendothelium
Basement membrane
Lumen
Elastic lamina
Tunica adventitia
Tunica media
Tunica intima:
Endothelium
Subendothelium
Basement membrane
Valve cusp
Elastic lamina
Arterioles
Capillary bed
Venules
Artery
Vein
Cusps of valve
Lumen
From heart
To heart



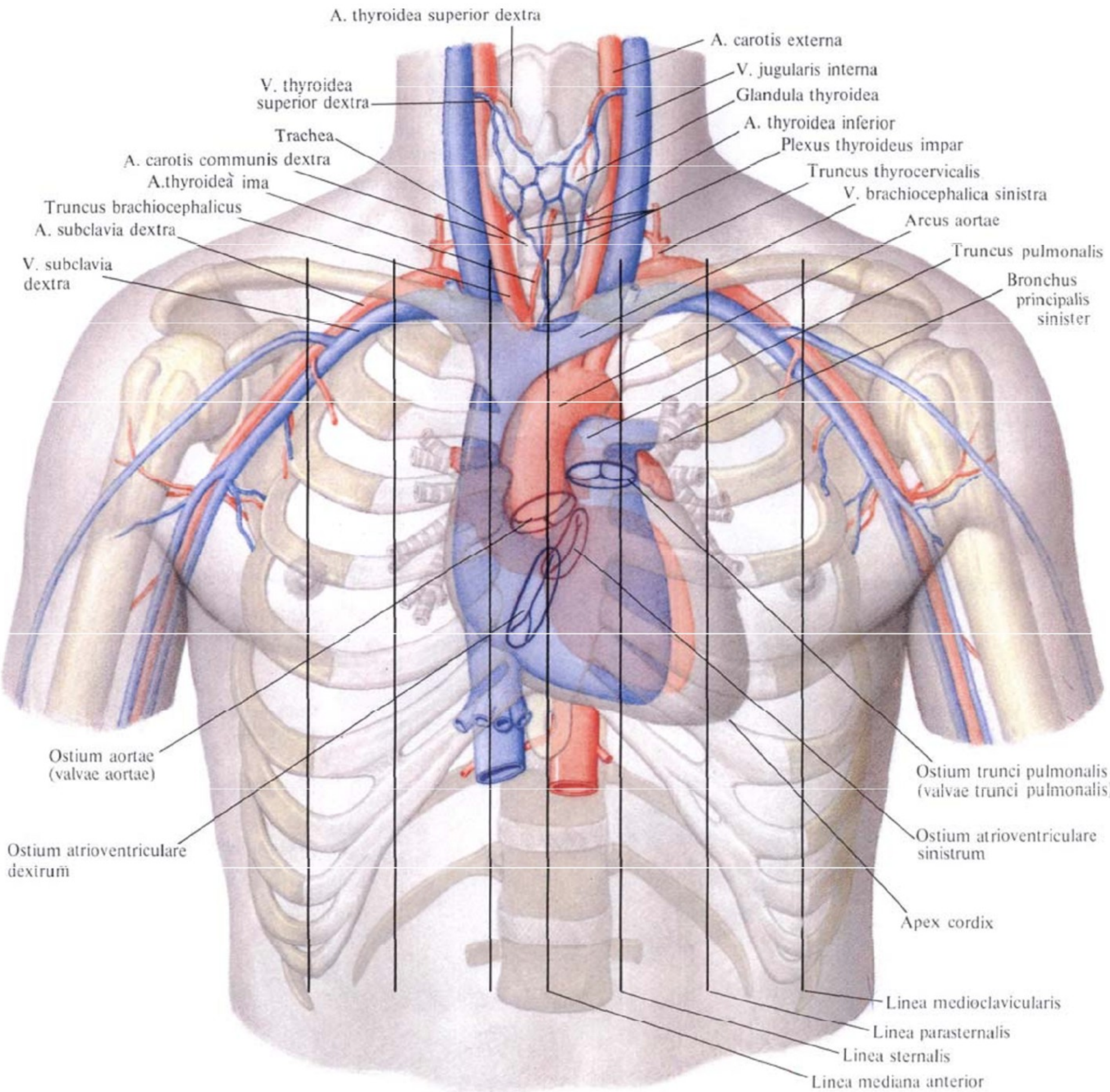
Cartilago thyroidea
Lig. cricothyroideum
M. cricothyroideus
Ganglion cervicale medium
N. vagus dexter
Trachea
A. cervicalis ascendens
A. thyroidea inferior
A. cervicalis superficialis
Truncus thyrocervicalis
A. suprascapularis
A. transversa cervicis
A. subclavia dextra
V. brachiocephalica dextra
V. brachiocephalica sinistra
V. cava superior
Pars ascendens aortae
A. pulmonalis dextra
V. cava superior
Vv. pulmonales
Bronchi lobares et segmentales
N. laryngeus inferior
N. phrenicus sinister
M. scalenus anterior
A. subclavia sinistra
Plexus brachialis
A. carotis communis sinistra
N. vagus sinister
Arcus aortae
Lig. arteriosum
N. laryngeus recurrens
Bifurcatio trunci pulmonalis
Truncus pulmonalis
Vv. pulmonales
Sinus trunci pulmonalis
Conus arteriosus
Auricula sinistra
Bronchi lobares et segmentales
Auricula dextra
Diaphragma
Pericardium
Sulcus interventricularis anterior



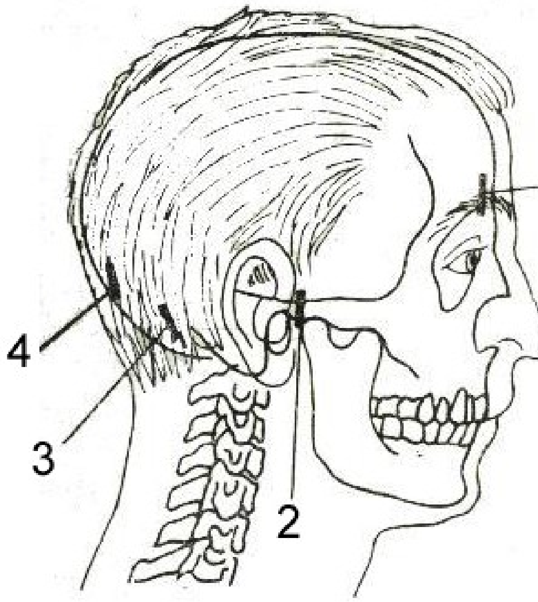
Cartilago thyroidea
Lig. cricothyroideum
M. cricothyroideus
Ganglion cervicale medium
N. vagus dexter
Trachea
A. cervicalis ascendens
A. thyroidea inferior
A. cervicalis superficialis
Truncus thyrocervicalis
A. suprascapularis
A. transversa cervicis
A. subclavia dextra
V. brachiocephalica dextra
V. brachiocephalica sinistra
V. cava superior
Pars ascendens aortae
A. pulmonalis dextra
V. cava superior
Vv. pulmonales
Bronchi lobares et segmentales
N. laryngeus inferior
N. phrenicus sinister
M. scalenus anterior
A. subclavia sinistra
Plexus brachialis
A. carotis communis sinistra
N. vagus sinister
Arcus aortae
Lig. arteriosum
N. laryngeus recurrens
Bifurcatio trunci pulmonalis
Truncus pulmonalis
Vv. pulmonales
Sinus trunci pulmonalis
Conus arteriosus
Auricula sinistra
Bronchi lobares et segmentales
Auricula dextra
Diaphragma
Ventriculus dexter
Pericardium
Sulcus interventricularis anterior
Apex cordis
Ventriculus sinister



A. carotis communis dextra
R. superficialis
A. transversa colli
A. scapularis dorsalis
Truncus brachiocephalicus
A. intercostalis suprema
A. thoracica superior
R. clavicularis
R. acromialis
R. deltoideus
A. toracoacromialis
A. axillaris dextra
R. pectoralis
V. cava superior
A. circumflexa scapulae
A. coronaria dextra
A. pericardiacophrenica
Анастомоз между a. profunda brachii и a. circumflexa humeri posterior
A. thoracica interna
V. cava inferior
Aa. intercostales posteriores
Ventriculus dexter
A. phrenica superior
A. phrenica inferior
A. hepatica communis
A. suprarenalis inferior
A. renalis dextra
A. testicularis
Pars abdominalis aortae
A. iliaca communis dextra
A. glutea superior
A. sacralis lateralis
A. obturatoria
A. glutea inferior
A. circumflexa iliaca superficialis
A. pudenda interna
R. ascendens
Aa. pudendae externae
R. acetabularis (a. circumflexa femoris medialis)
A. profunda femoris
A. cervicalis ascendens
A. thyroidea inferior
A. cervicalis profunda
A. vertebralis
Truncus thyrocervicalis
A. subclavia sinistra
A. suprascapularis
Arcus aortae
Pars descendens aortae
A. thoracica lateralis
Pars ascendens aortae
A. circumflexa humeri posterior
A. circumflexa humeri anterior
A. subscapularis
A. thoracodorsalis
A. brachialis
A. coronaria sinistra
A. profunda brachii
Ventriculus sinister
A. musculophrenica
Pars thoracica aortae
A. epigastrica superior
A. gastrica sinistra
Truncus celiacus
A. lienalis
A. mesenterica superior
Aa. lumbales
A. mesenterica inferior
A. sacralis mediana
R. lumbalis
R. iliacus
A. iliolumbalis
A. epigastrica inferior
A. iliaca interna
A. iliaca externa
A. epigastrica superficialis
A. circumflexa iliaca profunda
R. pubicus
Rr. spinales
A. femoralis
Rr. inguinales
A. circumflexa femoris lateralis
R. ascendens
R. descendens
A. circumflexa femoris lateralis
A. circumflexa femoris medialis



Points of palpation of some arteries and nerves of the head

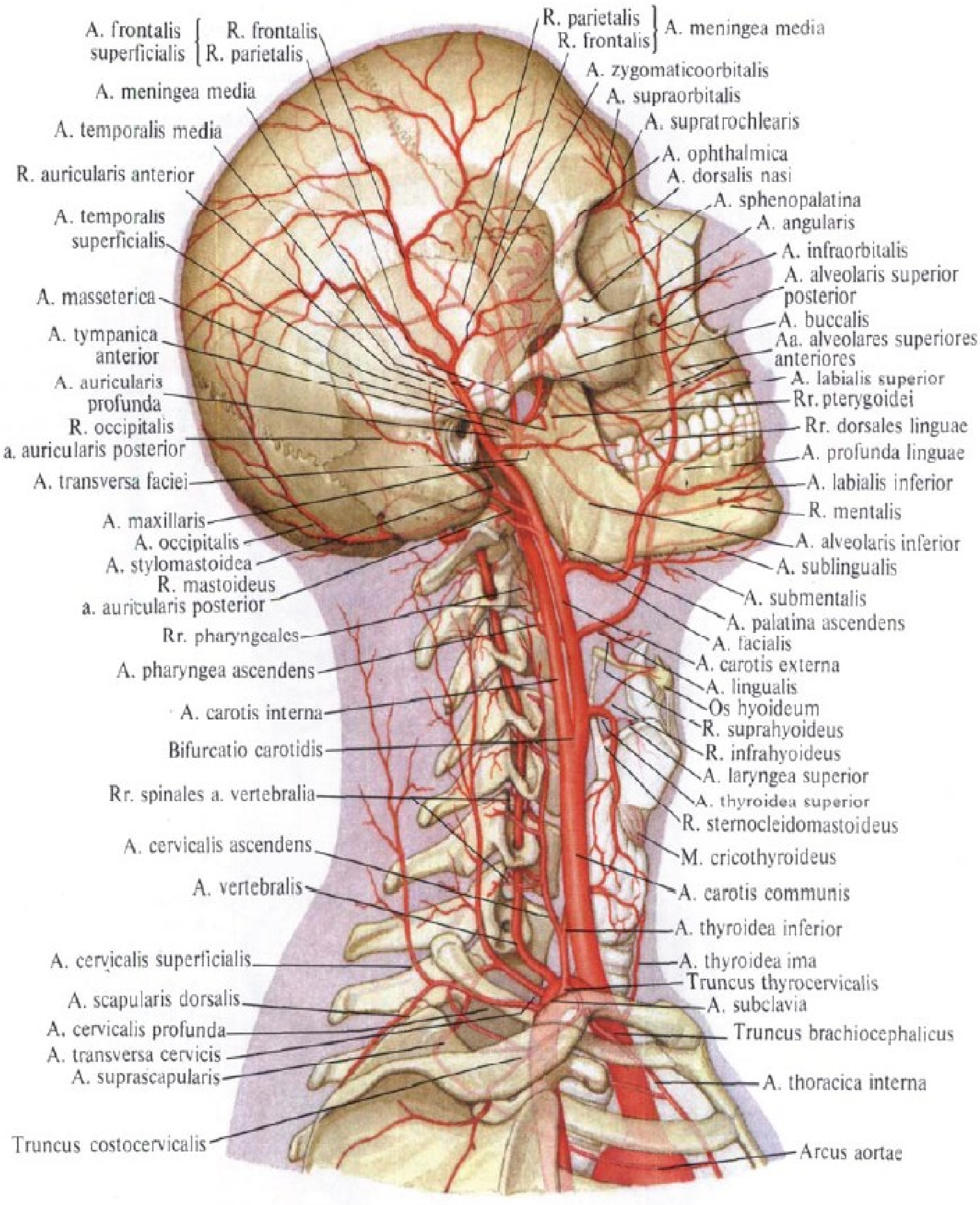


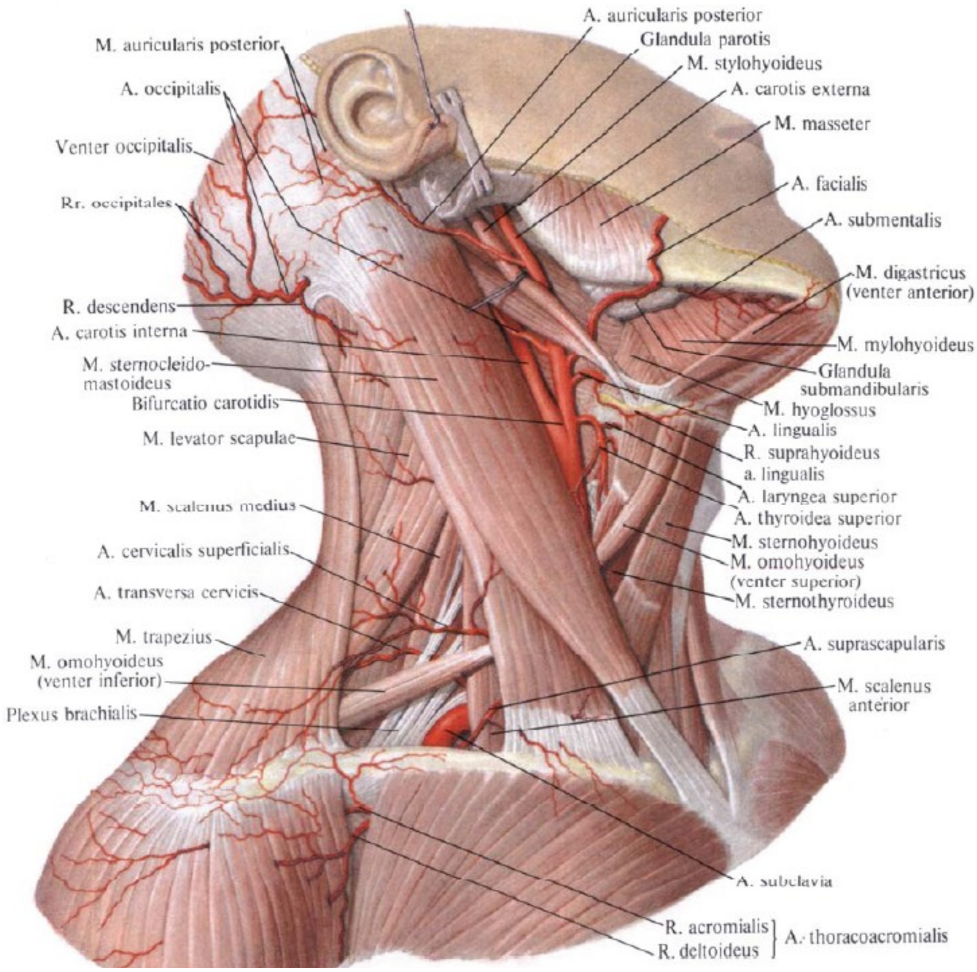
1 – a. supraorbitalis;

2 – a. temporalis superficialis;

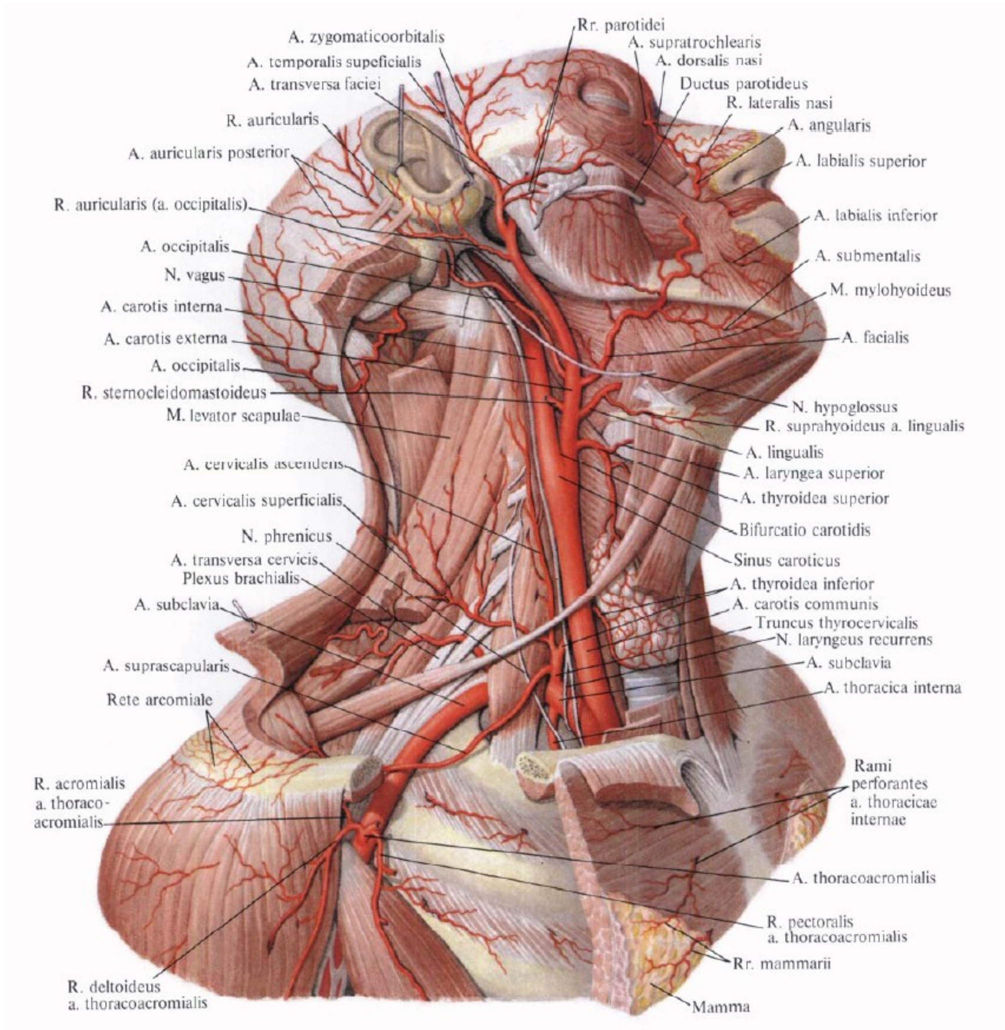
3 – a occipitalis;

4 – n. occipitalis (Arnald).

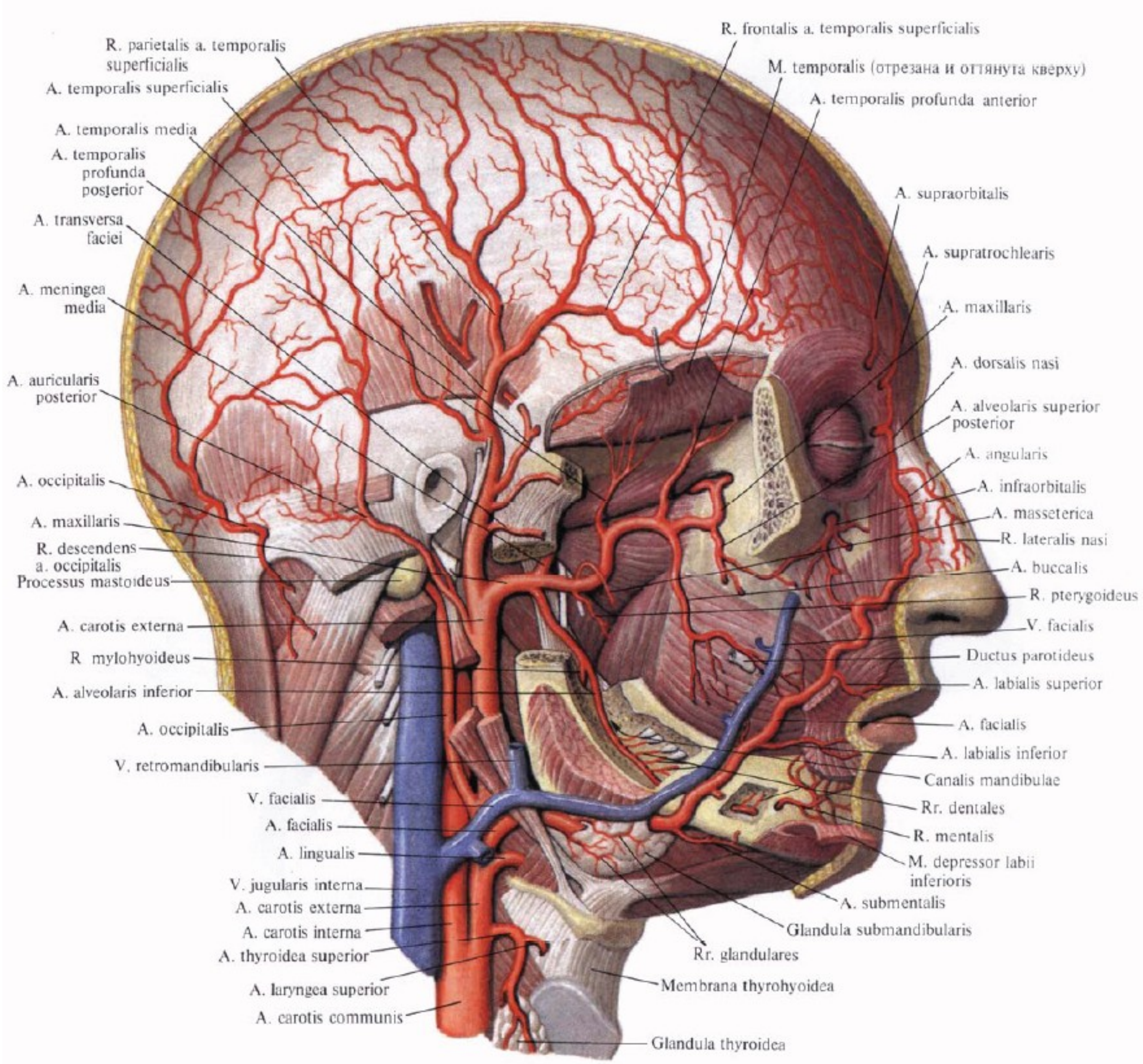

A. frontalis superficialis
R. frontalis
R. parietalis
R. parietalis
R. frontalis
A. meningea media
A. zygomaticoorbitalis
A. supraorbitalis
A. meningea media
A. supratrochlearis
A. temporalis media
A. ophthalmica
A. dorsalis nasi
R. auricularis anterior
A. sphenopalatina
A. angularis
A. temporalis superficialis
A. infraorbitalis
A. alveolaris superior posterior
A. masseterica
A. buccalis
A. tympanica anterior
Aa. alveolares superiores anteriores
A. labialis superior
A. auricularis profunda
Rr. pterygoidei
R. occipitalis a. auricularis posterior
Rr. dorsales linguae
A. profunda linguae
A. transversa faciei
A. labialis inferior
R. mentalis
A. maxillaris
A. occipitalis
A. alveolaris inferior
A. stylomastoidea
A. sublingualis
R. mastoideus a. auricularis posterior
A. submentalis
A. palatina ascendens
Rr. pharyngeales
A. facialis
A. pharyngea ascendens
A. carotis externa
A. lingualis
A. carotis interna
Os hyoideum
R. suprahyoideus
Bifurcatio carotidis
R. infrahyoideus
A. laryngea superior
Rr. spinales a. vertebralia
A. thyroidea superior
R. sternocleidomastoideus
A. cervicalis ascendens
M. cricothyroideus
A. vertebralis
A. carotis communis
A. thyroidea inferior
A. cervicalis superficialis
A. thyroidea ima
Truncus thyrocervicalis
A. scapularis dorsalis
A. subclavia
A. cervicalis profunda
Truncus brachiocephalicus
A. transversa cervicis
A. suprascapularis
A. thoracica interna
Truncus costocervicalis
Arcus aortae



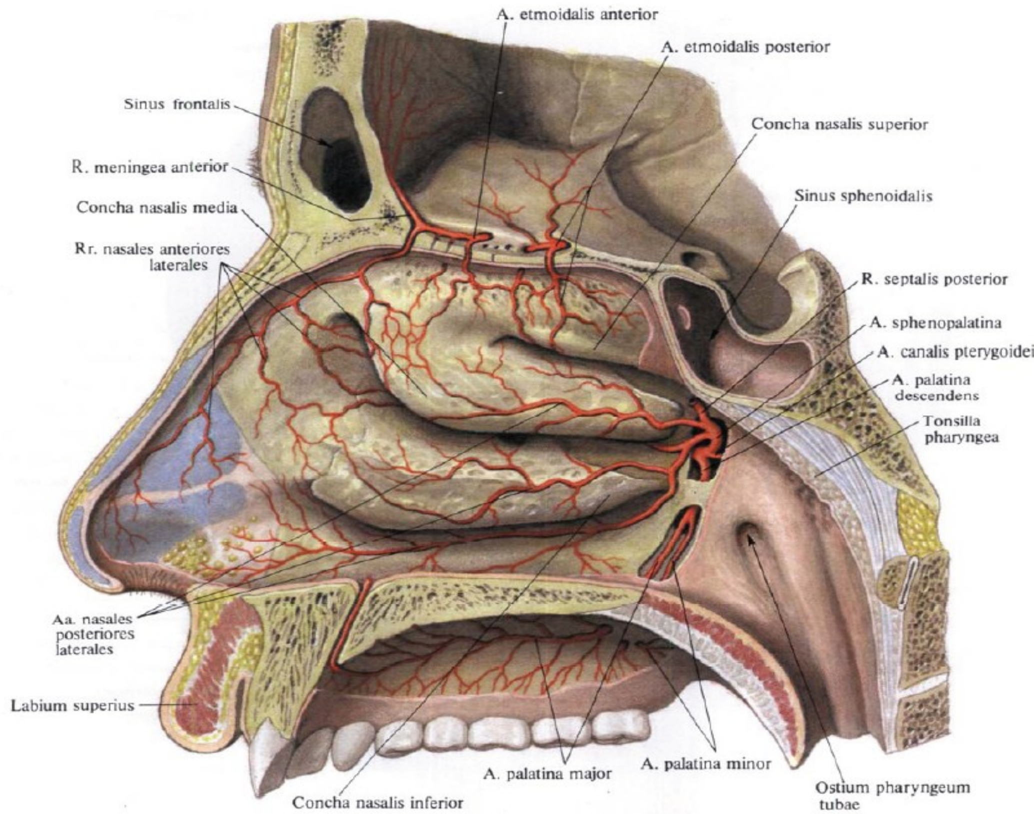
A. auricularis posterior
M. auricularis posterior
Glandula parotis
M. stylohyoideus
A. occipitalis
A. carotis externa
M. masseter
Venter occipitalis
A. facialis
Rr. occipitales
A. submentalis
M. digastricus
(venter anterior)
R. descendens
A. carotis interna
M. mylohyoideus
M. sternocleido-
mastoideus
Glandula
submandibularis
Bifurcatio carotidis
M. hyoglossus
A. lingualis
M. levator scapulae
R. suprahyoideus
a. lingualis
A. laryngea superior
M. scalenus medius
A. thyroidea superior
M. sternohyoideus
A. cervicalis superficialis
M. omohyoideus
(venter superior)
A. transversa cervicis
M. sternothyroideus
M. trapezius
A. suprascapularis
M. omohyoideus
(venter inferior)
M. scalenus
anterior
Plexus brachialis
A. subclavia
R. acromialis
R. deltoideus
A. thoracoacromialis



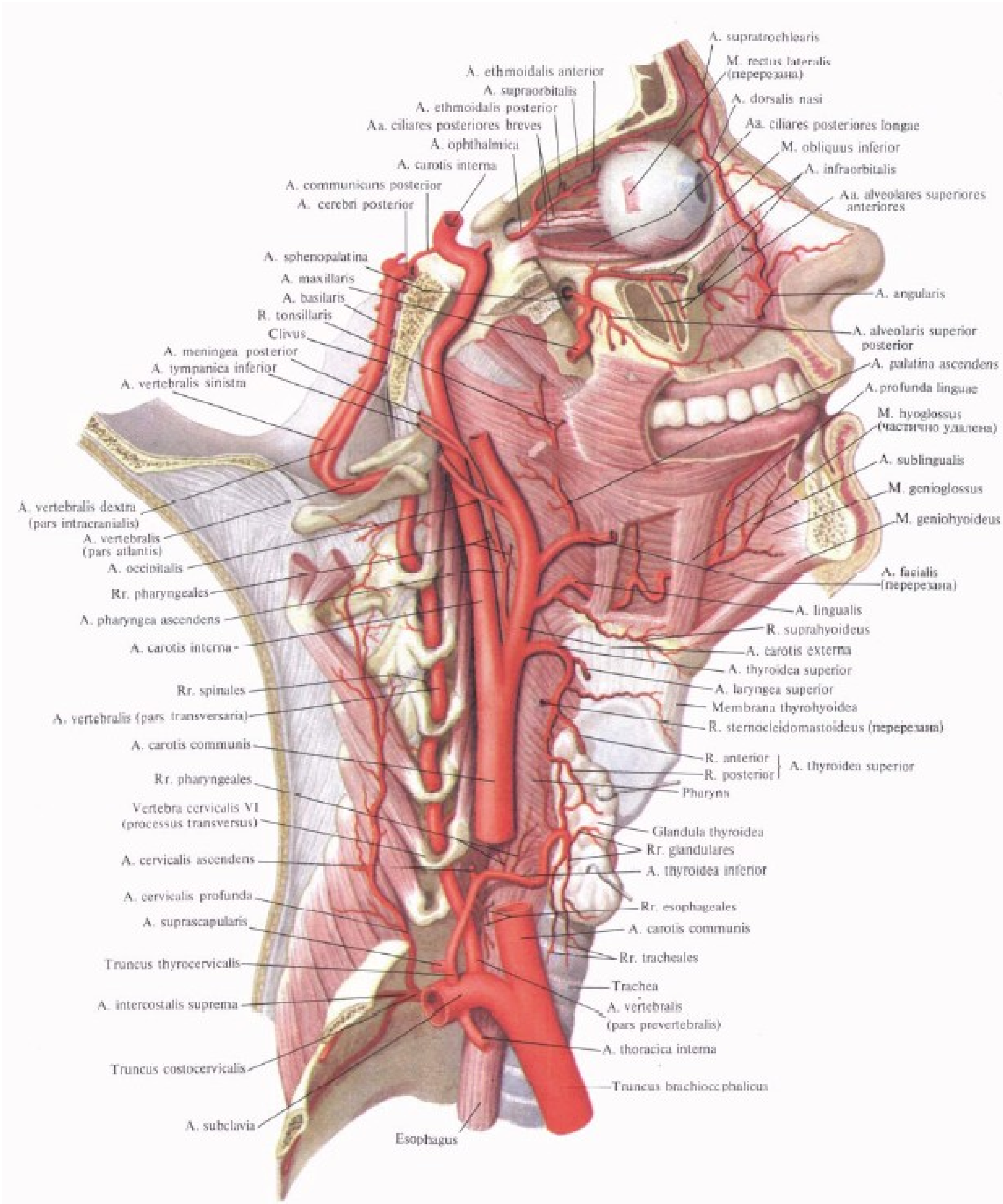
A. zygomaticoorbitalis
A. temporalis supeficialis
A. transversa faciei
R. auricularis
A. auricularis posterior
R. auricularis (a. occipitalis)
A. occipitalis
N. vagus
A. carotis interna
A. carotis externa
A. occipitalis
R. sternocleidomastoideus
M. levator scapulae
A. cervicalis ascendens
A. cervicalis superficialis
N. phrenicus
A. transversa cervicis
Plexus brachialis
A. subclavia
A. suprascapularis
Rete arcomiale
R. acromialis
a. thoraco-
acromialis
R. deltoideus
a. thoracoacromialis
Rr. parotidei
A. supratrochlearis
A. dorsalis nasi
Ductus parotideus
R. lateralis nasi
A. angularis
A. labialis superior
A. labialis inferior
A. submentalis
M. mylohyoideus
A. facialis
N. hypoglossus
R. suprahyoideus a. lingualis
A. lingualis
A. laryngea superior
A. thyroidea superior
Bifurcatio carotidis
Sinus caroticus
A. thyroidea inferior
A. carotis communis
Truncus thyrocervicalis
N. laryngeus recurrens
A. subclavia
A. thoracica interna
Rami
perforantes
a. thoracicae
internae
A. thoracoacromialis
R. pectoralis
a. thoracoacromialis
Rr. mammarii
Mamma



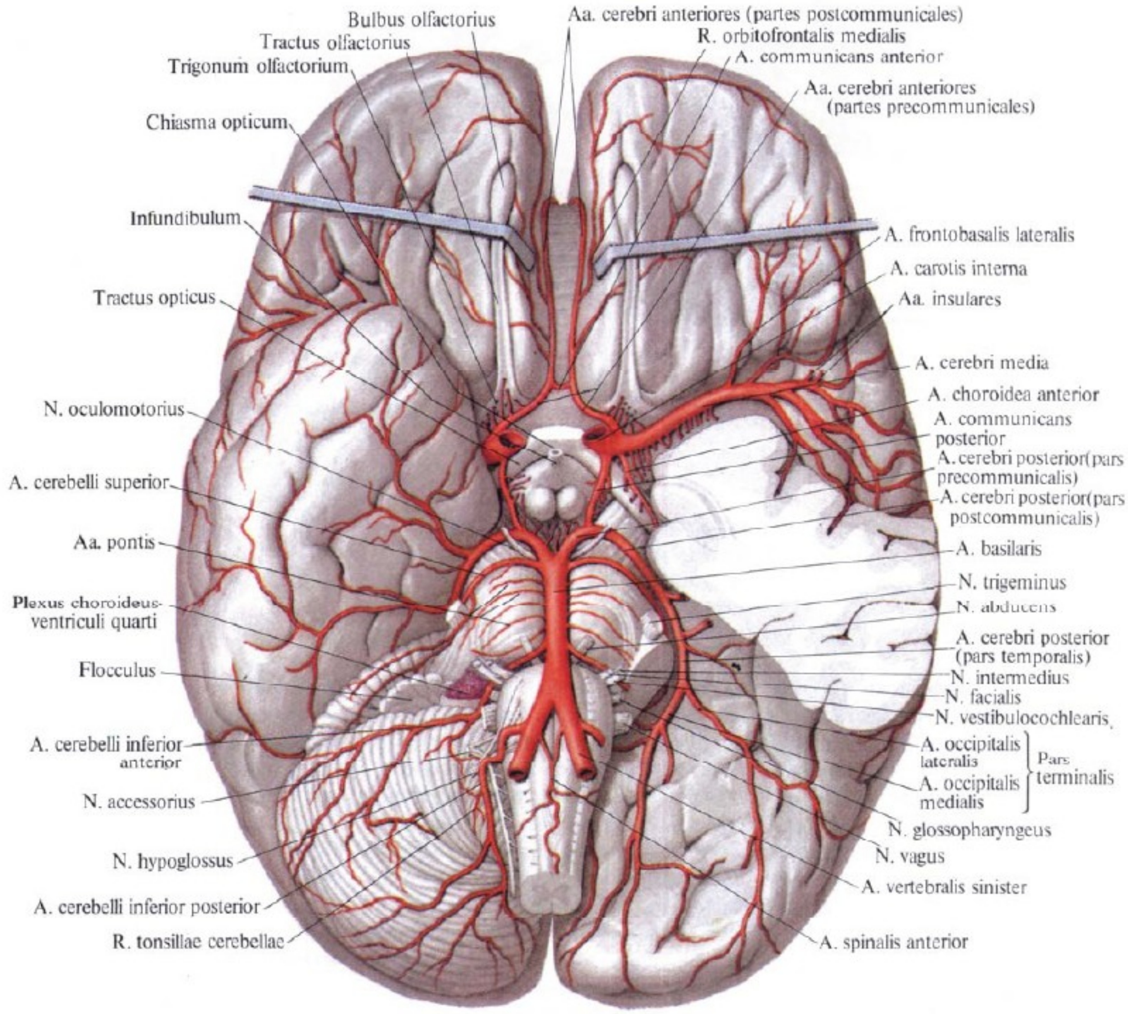
R. parietalis a. temporalis superficialis
A. temporalis superficialis
A. temporalis media
A. temporalis profunda posterior
A. transversa faciei
A. meningea media
A. auricularis posterior
A. occipitalis
A. maxillaris
R. descendens a. occipitalis
Processus mastoideus
A. carotis externa
R mylohyoideus
A. alveolaris inferior
A. occipitalis
V. retromandibularis
V. facialis
A. facialis
A. lingualis
V. jugularis interna
A. carotis externa
A. carotis interna
A. thyroidea superior
A. laryngea superior
A. carotis communis
R. frontalis a. temporalis superficialis
M. temporalis (отрезана и оттянута кверху)
A. temporalis profunda anterior
A. supraorbitalis
A. supratrochlearis
A. maxillaris
A. dorsalis nasi
A. alveolaris superior posterior
A. angularis
A. infraorbitalis
A. masseterica
R. lateralis nasi
A. buccalis
R. pterygoideus
V. facialis
Ductus parotideus
A. labialis superior
A. facialis
A. labialis inferior
Canalis mandibulae
Rr. dentales
R. mentalis
M. depressor labii inferioris
A. submentalis
Glandula submandibularis
Rr. glandulares
Membrana thyrohyoidea
Glandula thyroidea

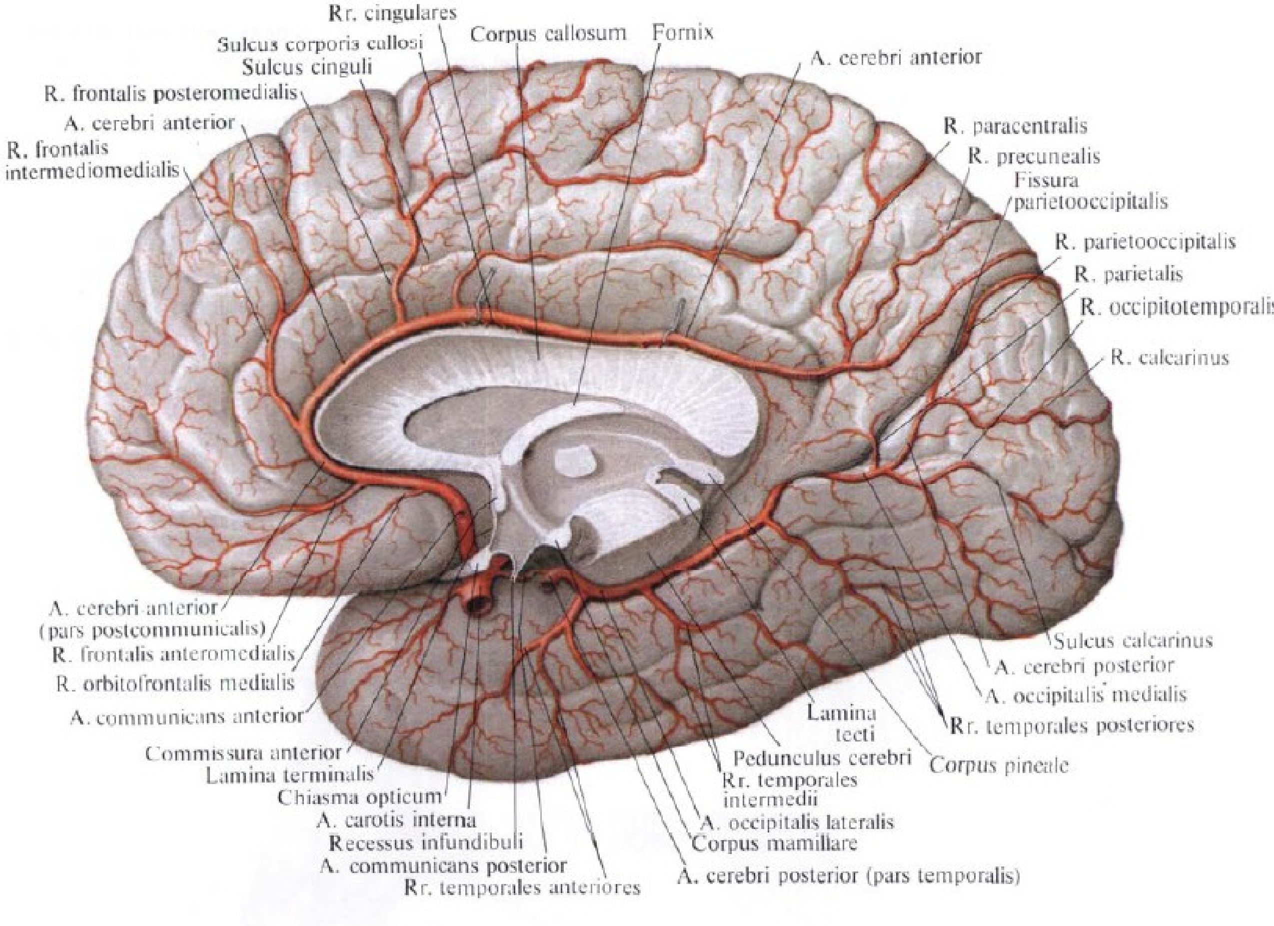


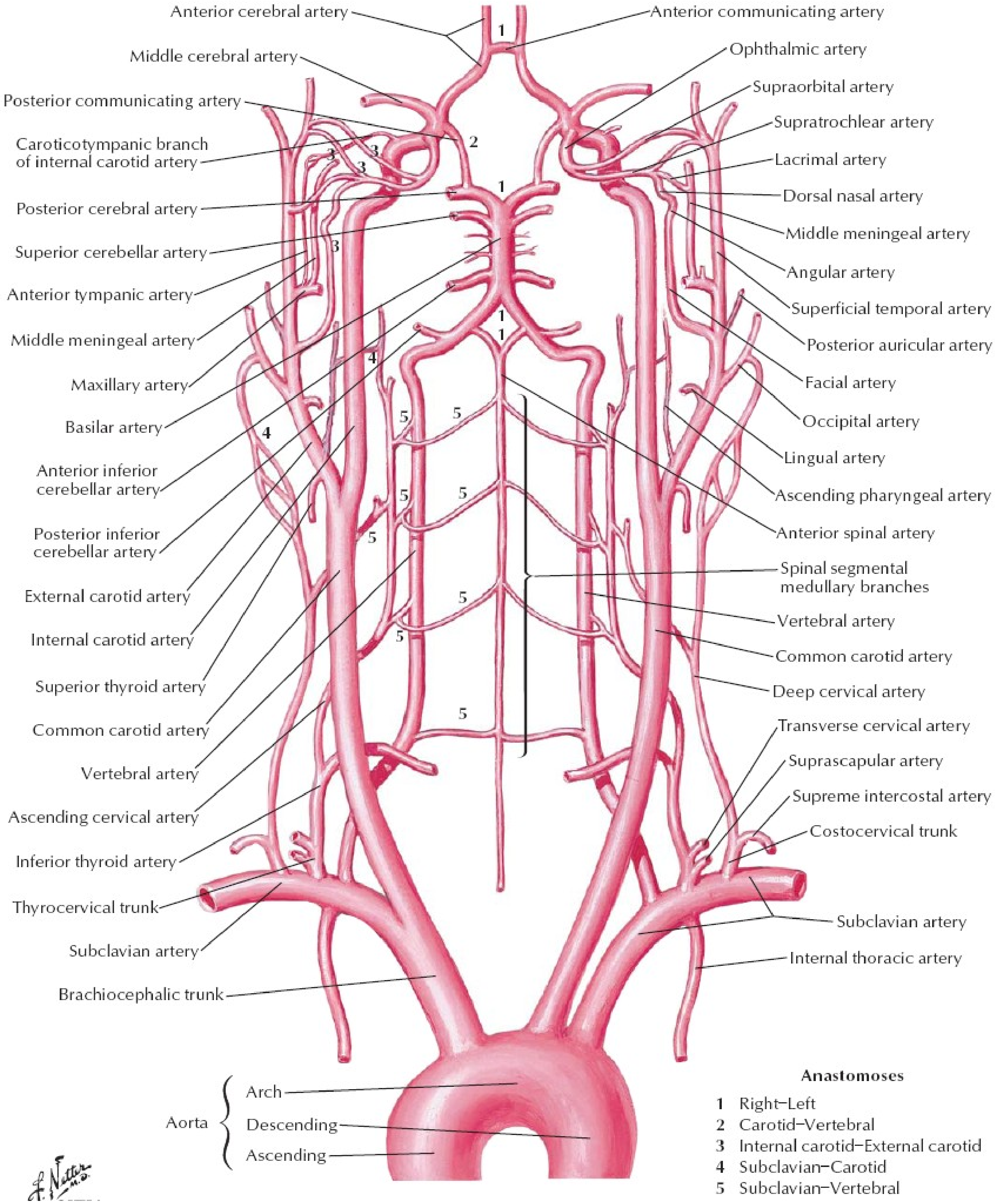
A. etmoidalis anterior
A. etmoidalis posterior
Sinus frontalis
Concha nasalis superior
R. meningea anterior
Sinus sphenoidalis
Concha nasalis media
Rr. nasales anteriores laterales
R. septalis posterior
A. sphenopalatina
A. canalis pterygoidei
A. palatina descendens
Tonsilla pharyngea
Aa. nasales posteriores laterales
Labium superius
A. palatina major
A. palatina minor
Concha nasalis inferior
Ostium pharyngeum tubae

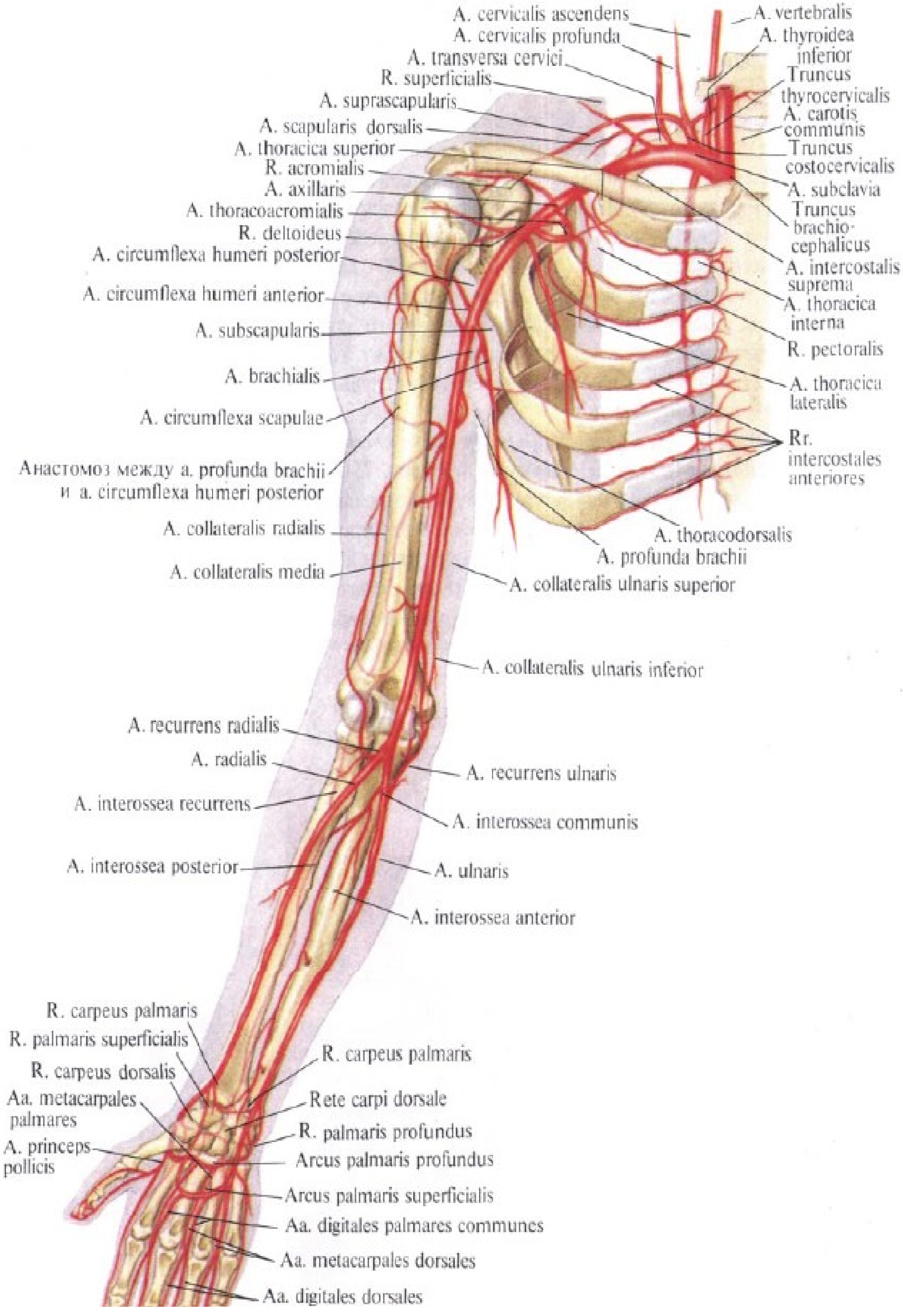


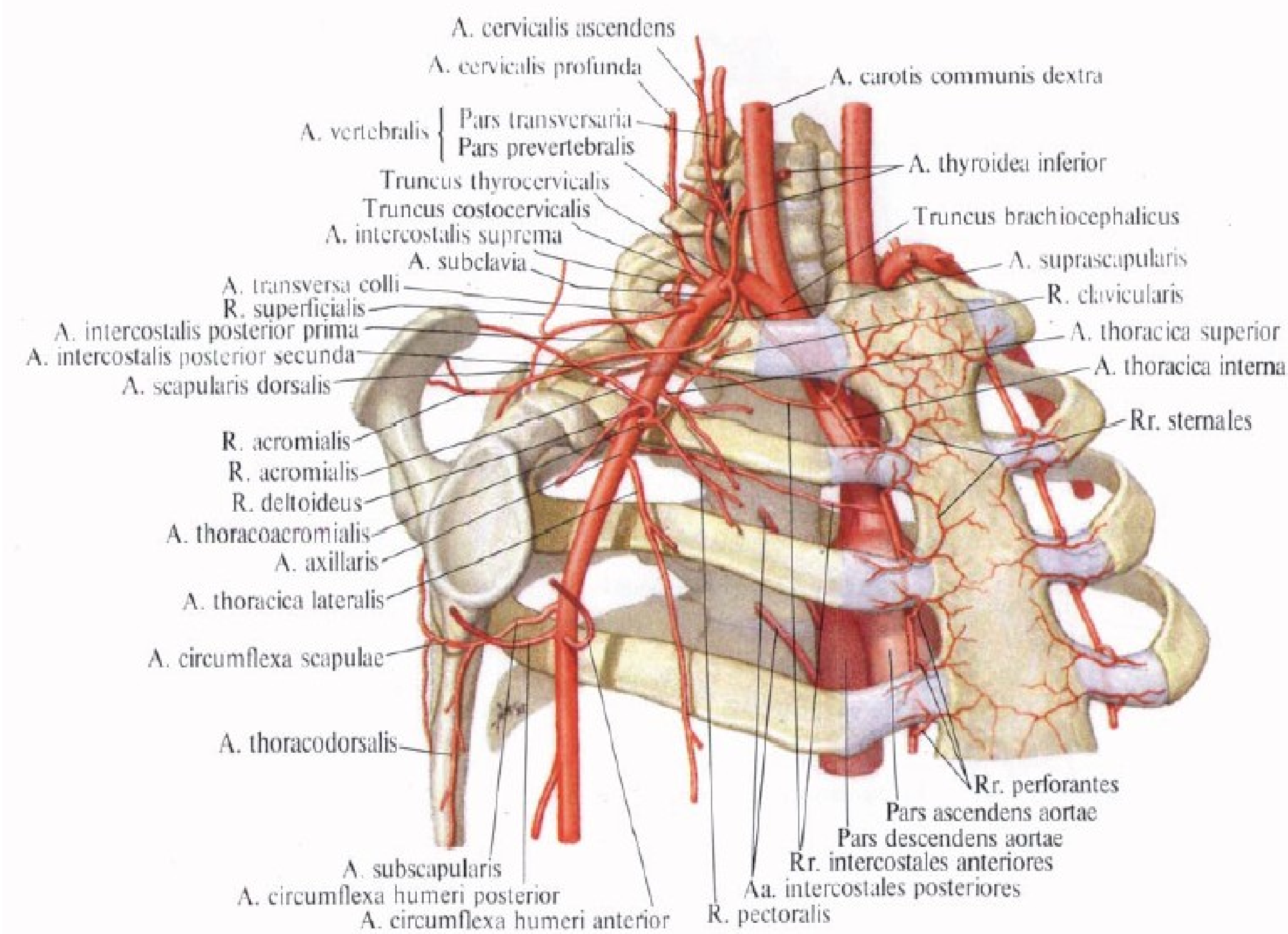
A. supratrochlearis
M. rectus lateralis (перерезана)
A. ethmoidalis anterior
A. supraorbitalis
A. dorsalis nasi
A. ethmoidalis posterior
Aa. ciliares posteriores longae
Aa. ciliares posteriores breves
A. ophthalmica
M. obliquus inferior
A. carotis interna
A. infraorbitalis
A. communicans posterior
A. cerebri posterior
Aa. alveolares superiores anteriores
A. sphenopalatina
A. maxillaris
A. angularis
A. basilaris
R. tonsillaris
Clivus
A. alveolaris superior posterior
A. meningea posterior
A. palatina ascendens
A. tympanica inferior
A. vertebralis sinistra
A. profunda linguae
M. hyoglossus (частично удалена)
A. sublingualis
M. genioglossus
A. vertebralis dextra (pars intracranialis)
M. geniohyoideus
A. vertebralis (pars atlantis)
A. occipitalis
A. facialis (перерезана)
Rr. pharyngeales
A. pharyngea ascendens
A. lingualis
R. suprahyoideus
A. carotis interna
A. carotis externa
A. thyroidea superior
Rr. spinales
A. laryngea superior
Membrana thyrohyoidea
A. vertebralis (pars transversaria)
R. sternocleidomastoideus (перерезана)
A. carotis communis
R. anterior
R. posterior
A. thyroidea superior
Rr. pharyngeales
Pharynx
Vertebra cervicalis VI (processus transversus)
Glandula thyroidea
Rr. glandulares
A. cervicalis ascendens
A. thyroidea inferior
A. cervicalis profunda
Rr. esophageales
A. suprascapularis
A. carotis communis
Rr. tracheales
Truncus thyrocervicalis
Trachea
A. intercostalis suprema
A. vertebralis (pars prevertebralis)
A. thoracica interna
Truncus costocervicalis
Truncus brachiocephalicus
A. subclavia
Esophagus

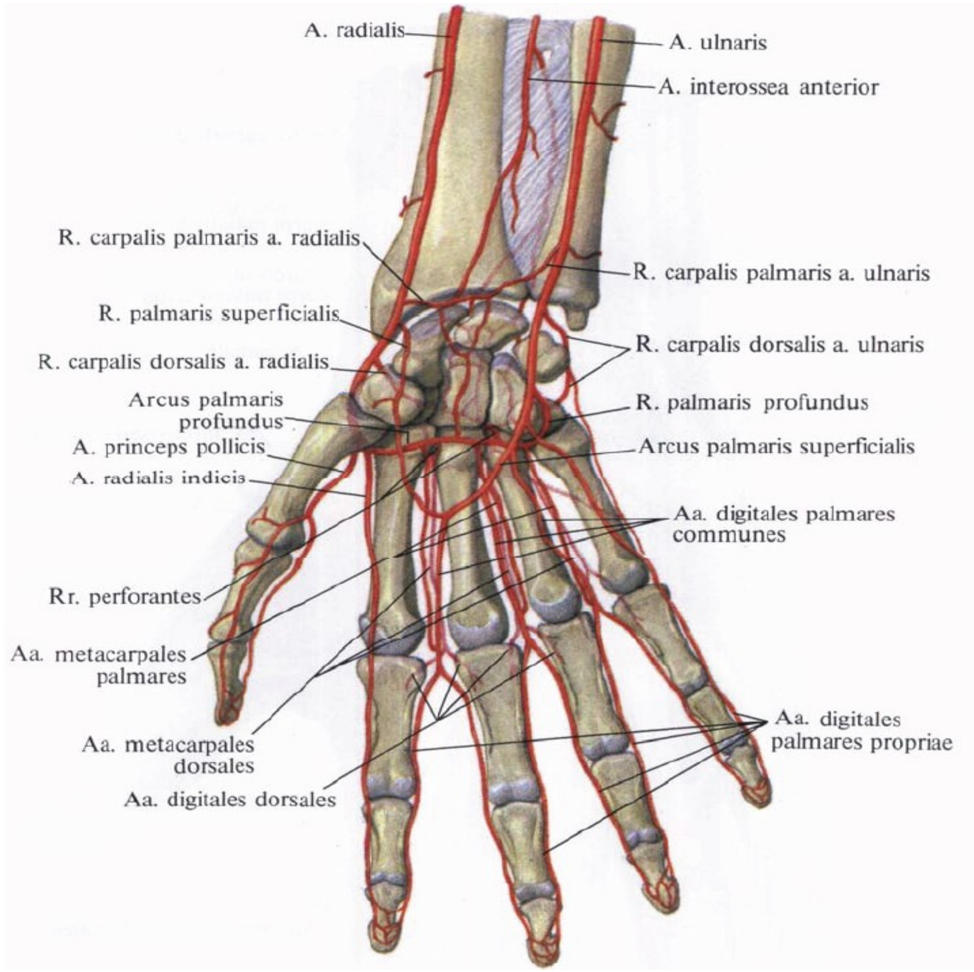

Bulbus olfactorius
Tractus olfactorius
Trigonum olfactorium
Chiasma opticum
Infundibulum
Tractus opticus
N. oculomotorius
A. cerebelli superior
Aa. pontis
Plexus choroideus ventriculi quarti
Flocculus
A. cerebelli inferior anterior
N. accessorius
N. hypoglossus
A. cerebelli inferior posterior
R. tonsillae cerebellae
Aa. cerebri anteriores (partes postcommunicales)
R. orbitofrontalis medialis
A. communicans anterior
Aa. cerebri anteriores (partes precommunicales)
A. frontobasalis lateralis
A. carotis interna
Aa. insulares
A. cerebri media
A. choroidea anterior
A. communicans posterior
A. cerebri posterior(pars precommunicalis)
A. cerebri posterior(pars postcommunicalis)
A. basilaris
N. trigeminus
N. abducens
A. cerebri posterior (pars temporalis)
N. intermedius
N. facialis
N. vestibulocochlearis
A. occipitalis lateralis
A. occipitalis medialis
Pars terminalis
N. glossopharyngeus
N. vagus
A. vertebralis sinister
A. spinalis anterior

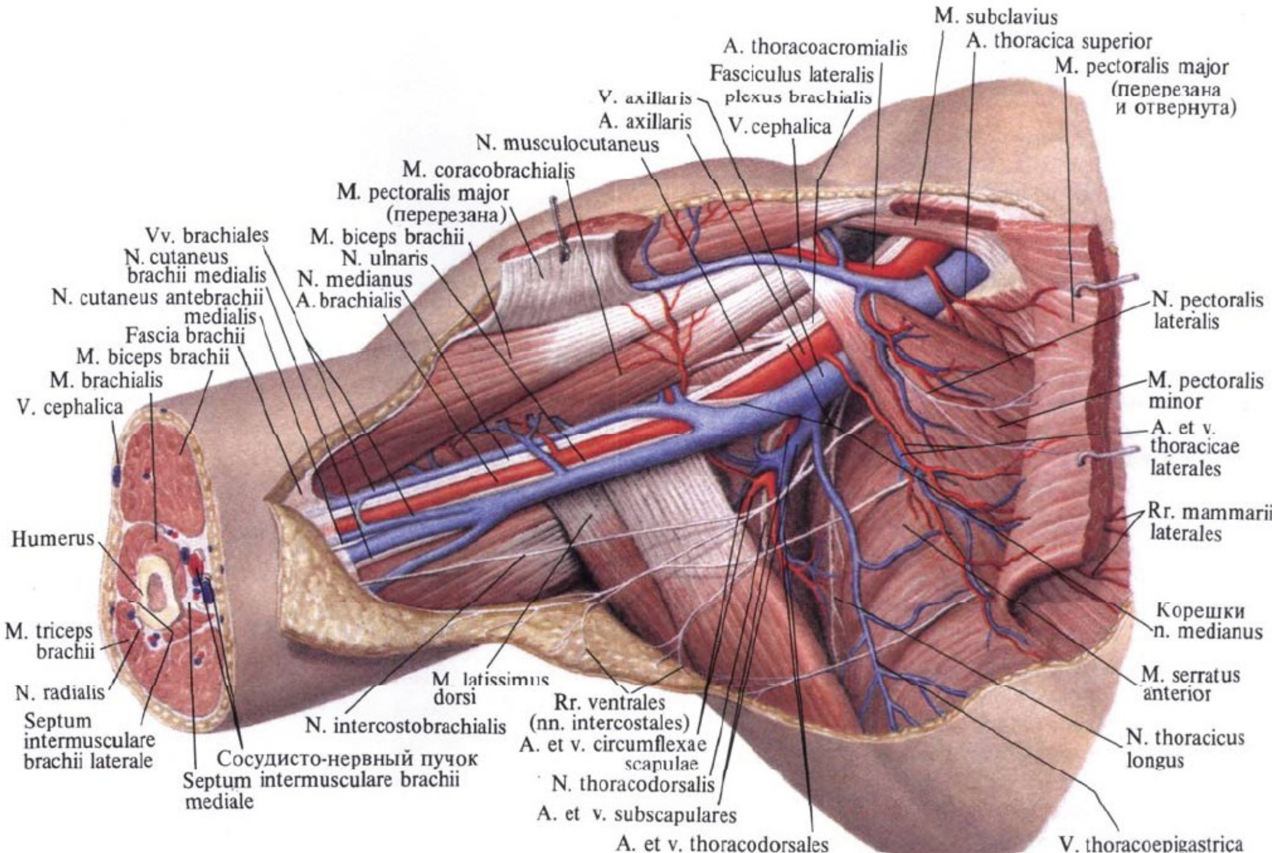

Rr. cingulares
Sulcus corporis callosi
Sulcus cinguli
Corpus callosum
Fornix
A. cerebri anterior
R. frontalis posteromedialis
A. cerebri anterior
R. frontalis intermediomedialis
R. paracentralis
R. precunealis
Fissura parietooccipitalis
R. parietooccipitalis
R. parietalis
R. occipitotemporalis
R. calcarinus
A. cerebri anterior (pars postcommunicalis)
R. frontalis anteromedialis
R. orbitofrontalis medialis
A. communicans anterior
Commissura anterior
Lamina terminalis
Chiasma opticum
A. carotis interna
Recessus infundibuli
A. communicans posterior
Rr. temporales anteriores
Sulcus calcarinus
A. cerebri posterior
A. occipitalis medialis
Rr. temporales posteriores
Lamina tecti
Pedunculus cerebri
Corpus pineale
Rr. temporales intermedii
A. occipitalis lateralis
Corpus mamillare
A. cerebri posterior (pars temporalis)

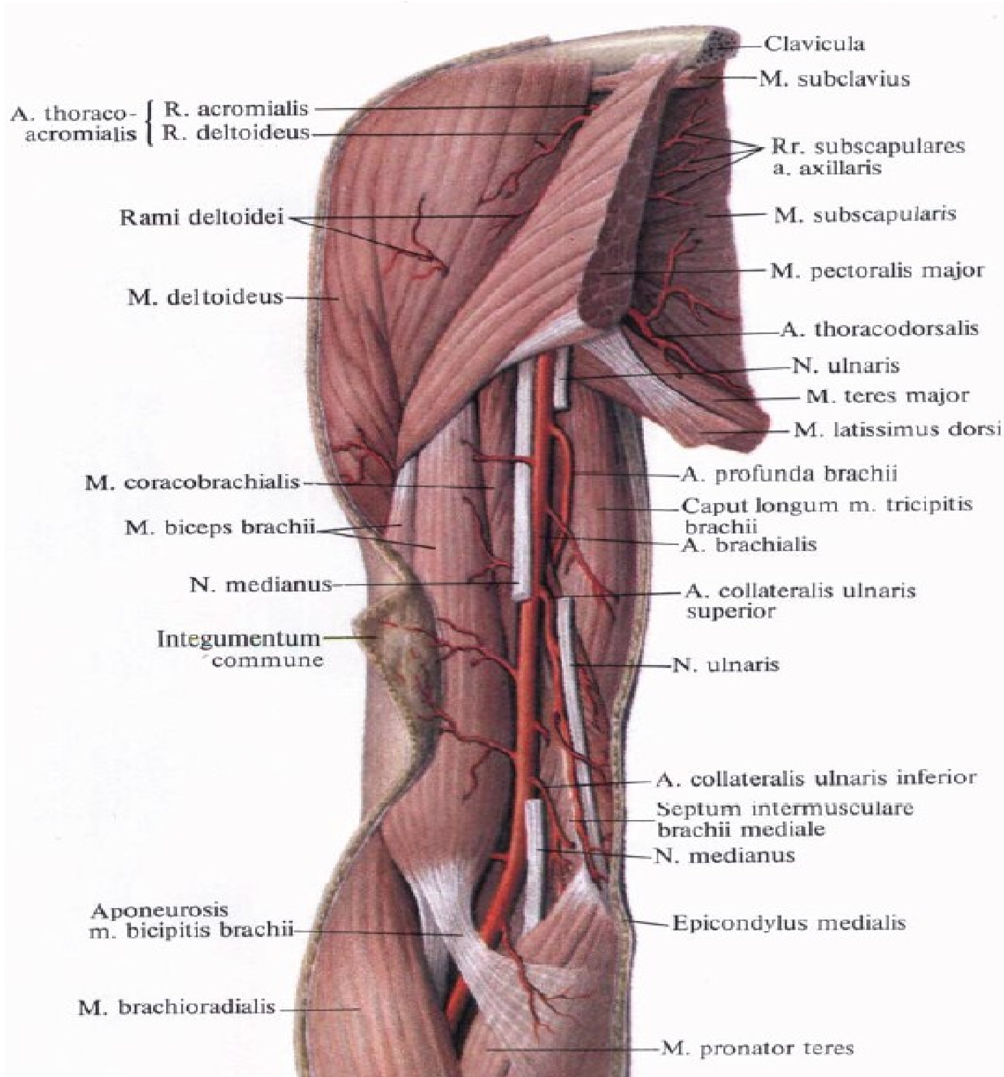

Anterior cerebral artery
Middle cerebral artery
Posterior communicating artery
Caroticotympanic branch of internal carotid artery
Posterior cerebral artery
Superior cerebellar artery
Anterior tympanic artery
Middle meningeal artery
Maxillary artery
Basilar artery
Anterior inferior cerebellar artery
Posterior inferior cerebellar artery
External carotid artery
Internal carotid artery
Superior thyroid artery
Common carotid artery
Vertebral artery
Ascending cervical artery
Inferior thyroid artery
Thyrocervical trunk
Subclavian artery
Brachiocephalic trunk
Anterior communicating artery
Ophthalmic artery
Supraorbital artery
Supratrochlear artery
Lacrimal artery
Dorsal nasal artery
Middle meningeal artery
Angular artery
Superficial temporal artery
Posterior auricular artery
Facial artery
Occipital artery
Lingual artery
Ascending pharyngeal artery
Anterior spinal artery
Spinal segmental medullary branches
Vertebral artery
Common carotid artery
Deep cervical artery
Transverse cervical artery
Suprascapular artery
Supreme intercostal artery
Costocervical trunk
Subclavian artery
Internal thoracic artery
Aorta
Arch
Descending
Ascending
Anastomoses
1 Right–Left
2 Carotid–Vertebral
3 Internal carotid–External carotid
4 Subclavian–Carotid
5 Subclavian–Vertebral
F. Netter M.D.

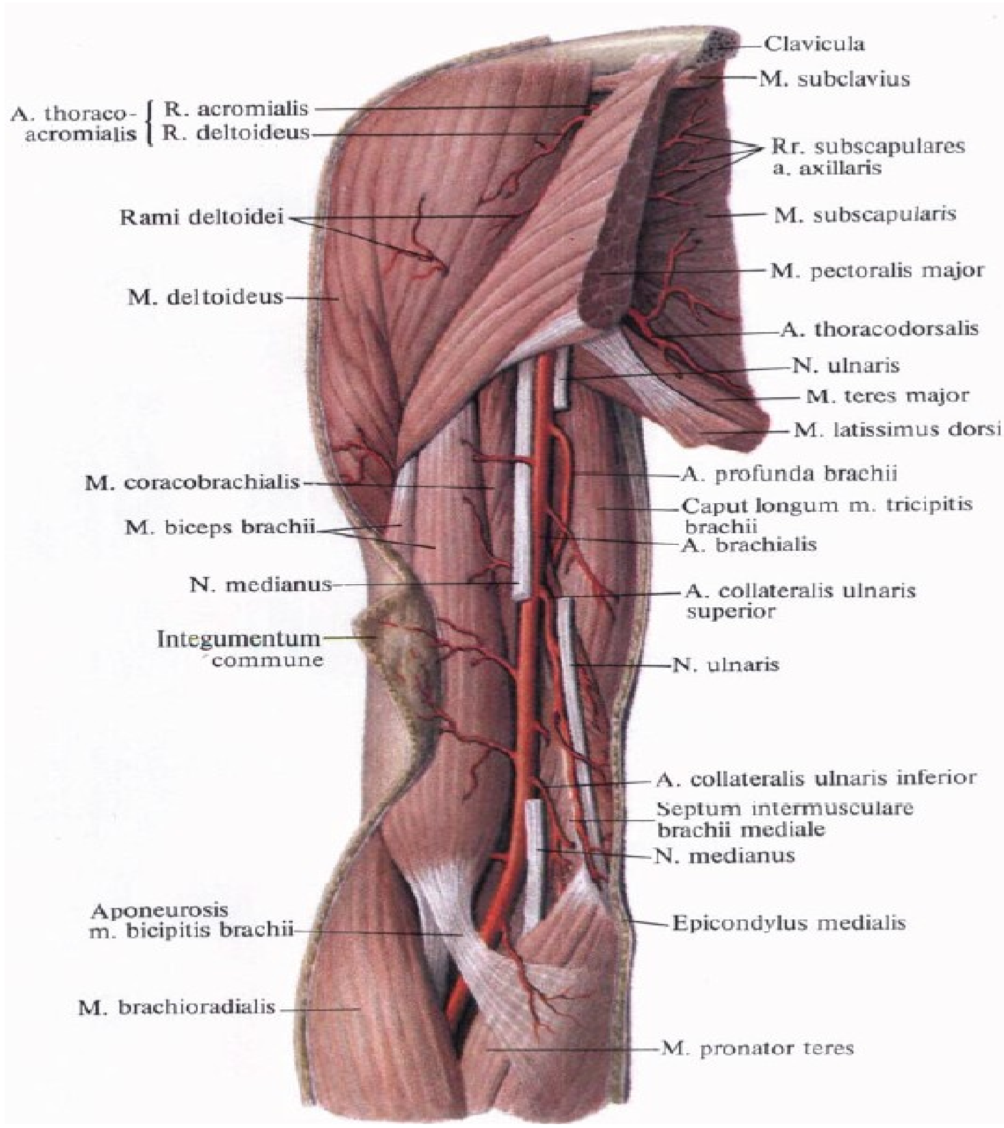

A. cervicalis ascendens
A. cervicalis profunda
A. transversa cervici
R. superficialis
A. suprascapularis
A. scapularis dorsalis
A. thoracica superior
R. acromialis
A. axillaris
A. thoracoacromialis
R. deltoideus
A. circumflexa humeri posterior
A. circumflexa humeri anterior
A. subscapularis
A. brachialis
A. circumflexa scapulae
Анастомоз между a. profunda brachii
и a. circumflexa humeri posterior
A. collateralis radialis
A. collateralis media
A. vertebralis
A. thyroidea inferior
Truncus thyrocervicalis
A. carotis communis
Truncus costocervicalis
A. subclavia
Truncus brachiocephalicus
A. intercostalis suprema
A. thoracica interna
R. pectoralis
A. thoracica lateralis
Rr. intercostales anteriores
A. thoracodorsalis
A. profunda brachii
A. collateralis ulnaris superior
A. collateralis ulnaris inferior
A. recurrens radialis
A. radialis
A. interossea recurrens
A. interossea posterior
A. recurrens ulnaris
A. interossea communis
A. ulnaris
A. interossea anterior
R. carpeus palmaris
R. palmaris superficialis
R. carpeus dorsalis
Aa. metacarpales palmares
A. princeps pollicis
R. carpeus palmaris
Rete carpi dorsale
R. palmaris profundus
Arcus palmaris profundus
Arcus palmaris superficialis
Aa. digitales palmares communes
Aa. metacarpales dorsales
Aa. digitales dorsales


A. cervicalis ascendens
A. cervicalis profunda
A. carotis communis dextra
A. vertebralis
Pars transversaria
Pars prevertebralis
A. thyroidea inferior
Truncus thyrocervicalis
Truncus costocervicalis
A. intercostalis suprema
Truncus brachiocephalicus
A. subclavia
A. suprascapularis
A. transversa colli
R. superficialis
R. clavicularis
A. intercostalis posterior prima
A. thoracica superior
A. intercostalis posterior secunda
A. thoracica interna
A. scapularis dorsalis
Rr. sternales
R. acromialis
R. acromialis
R. deltoideus
A. thoracoacromialis
A. axillaris
A. thoracica lateralis
A. circumflexa scapulae
A. thoracodorsalis
Rr. perforantes
Pars ascendens aortae
Pars descendens aortae
Rr. intercostales anteriores
Aa. intercostales posteriores
A. subscapularis
A. circumflexa humeri posterior
A. circumflexa humeri anterior
R. pectoralis

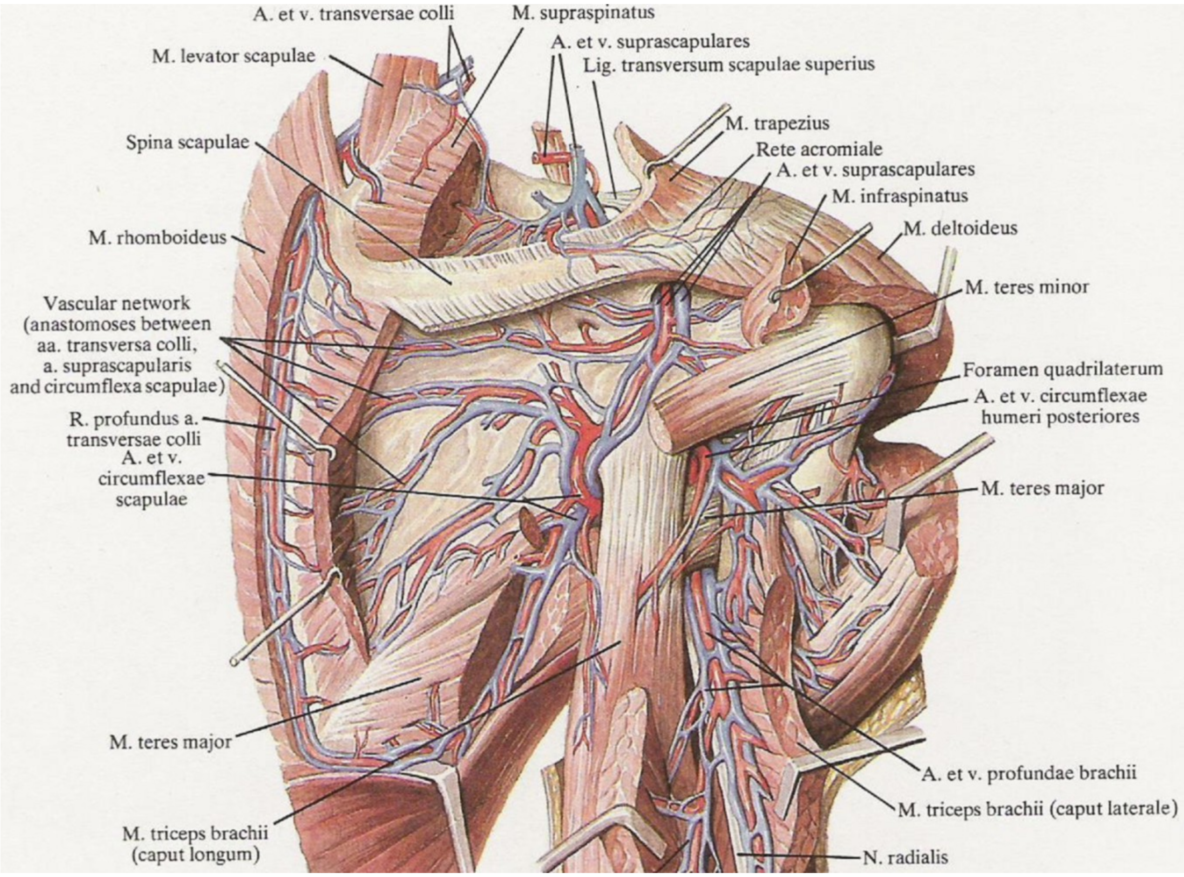

A. radialis
A. ulnaris
A. interossea anterior
R. carpalis palmaris a. radialis
R. carpalis palmaris a. ulnaris
R. palmaris superficialis
R. carpalis dorsalis a. ulnaris
R. carpalis dorsalis a. radialis
Arcus palmaris profundus
R. palmaris profundus
A. princeps pollicis
Arcus palmaris superficialis
A. radialis indicis
Aa. digitales palmares communes
Rr. perforantes
Aa. metacarpales palmares
Aa. digitales palmares propriae
Aa. metacarpales dorsales
Aa. digitales dorsales

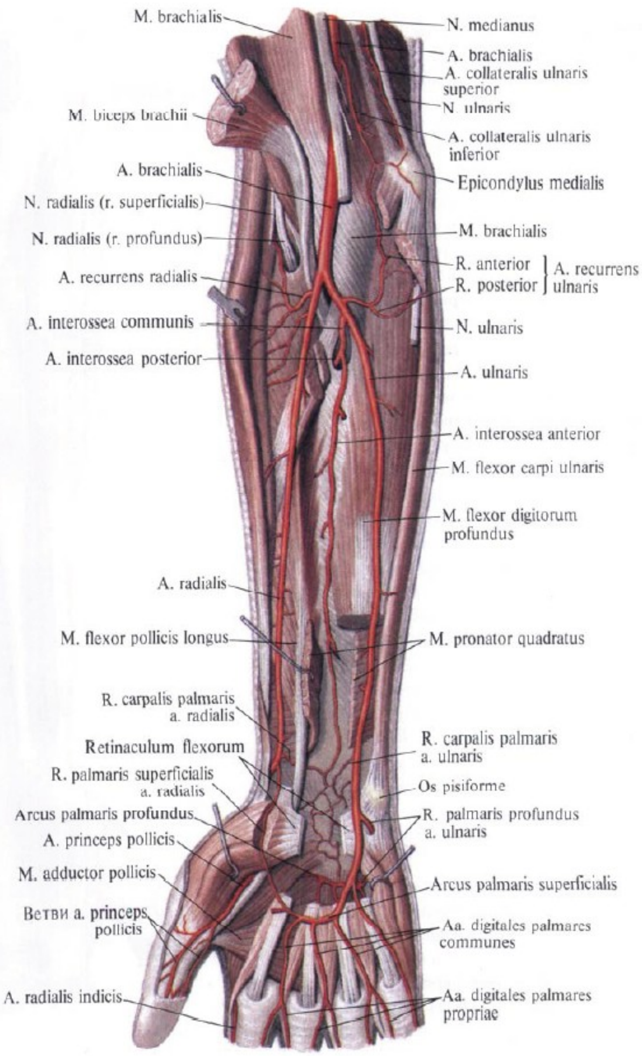

M. subclavius
A. thoracica superior
A. thoracoacromialis
Fasciculus lateralis
plexus brachialis
M. pectoralis major
(перерезана
и отвернута)
V. axillaris
A. axillaris
V. cephalica
N. musculocutaneus
M. coracobrachialis
M. pectoralis major
(перерезана)
Vv. brachiales
M. biceps brachii
N. ulnaris
N. cutaneus
brachii medialis
N. medianus
N. cutaneus antebrachii
medialis
A. brachialis
N. pectoralis
lateralis
Fascia brachii
M. biceps brachii
M. pectoralis
minor
M. brachialis
V. cephalica
A. et v.
thoracicae
laterales
Rr. mammarii
laterales
Humerus
Корешки
n. medianus
M. triceps
brachii
M. serratus
anterior
M. latissimus
dorsi
N. radialis
Rr. ventrales
(nn. intercostales)
N. intercostobrachialis
Septum
intermusculare
brachii laterale
A. et v. circumflexae
scapulae
N. thoracicus
longus
Сосудисто-нервный пучок
Septum intermusculare brachii
mediale
N. thoracodorsalis
A. et v. subscapulares
A. et v. thoracodorsales
V. thoracoepigastrica

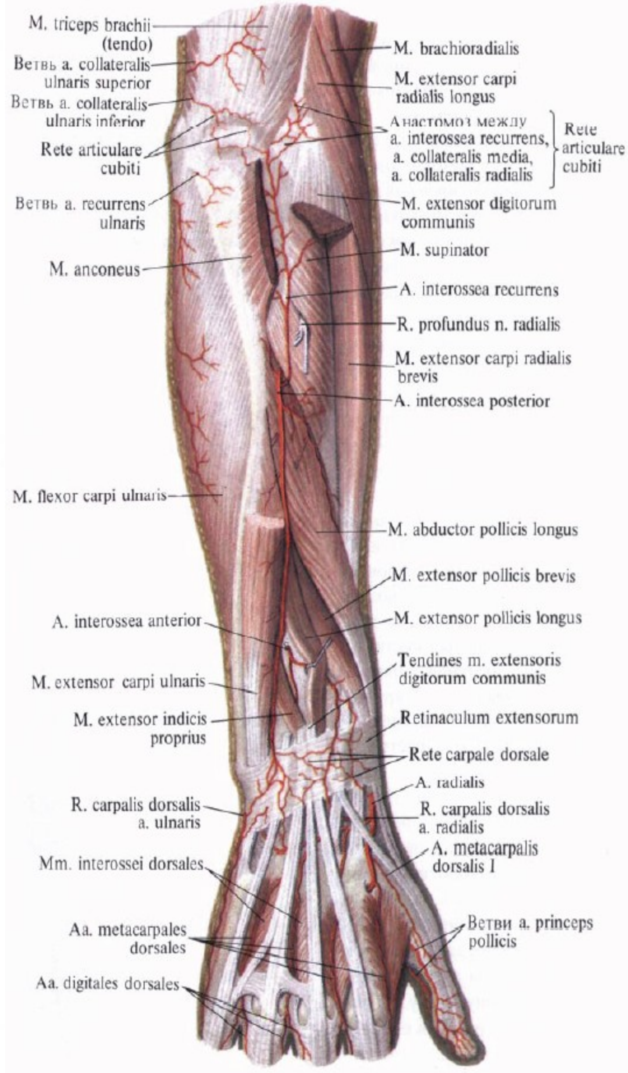

Clavicula
M. subclavius
A. thoraco-
acromialis
R. acromialis
R. deltoideus
Rr. subscapulares
a. axillaris
Rami deltoidei
M. subscapularis
M. pectoralis major
M. deltoideus
A. thoracodorsalis
N. ulnaris
M. teres major
M. latissimus dorsi
A. profunda brachii
M. coracobrachialis
Caput longum m. tricipitis
brachii
M. biceps brachii
A. brachialis
N. medianus
A. collateralis ulnaris
superior
Integumentum
commune
N. ulnaris
A. collateralis ulnaris inferior
Septum intermusculare
brachii mediale
N. medianus
Aponeurosis
m. bicipitis brachii
Epicondylus medialis
M. brachioradialis
M. pronator teres

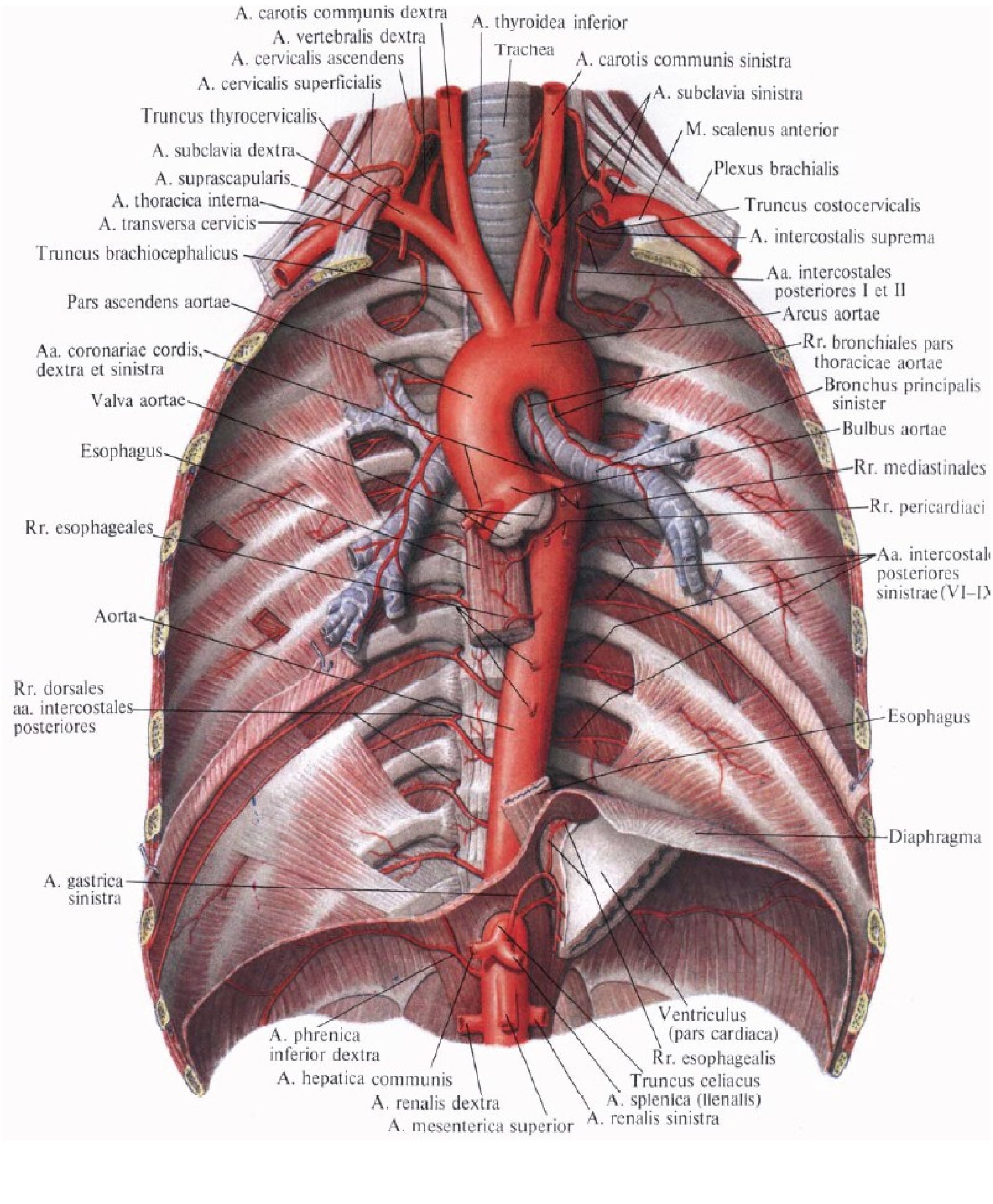


Clavicula
M. subclavius
A. thoraco-acromialis
R. acromialis
R. deltoideus
Rr. subscapulares a. axillaris
Rami deltoidei
M. subscapularis
M. pectoralis major
M. deltoideus
A. thoracodorsalis
N. ulnaris
M. teres major
M. latissimus dorsi
A. profunda brachii
M. coracobrachialis
Caput longum m. tricipitis brachii
M. biceps brachii
A. brachialis
N. medianus
A. collateralis ulnaris superior
Integumentum commune
N. ulnaris
A. collateralis ulnaris inferior
Septum intermusculare brachii mediale
N. medianus
Aponeurosis m. bicipitis brachii
Epicondylus medialis
M. brachioradialis
M. pronator teres

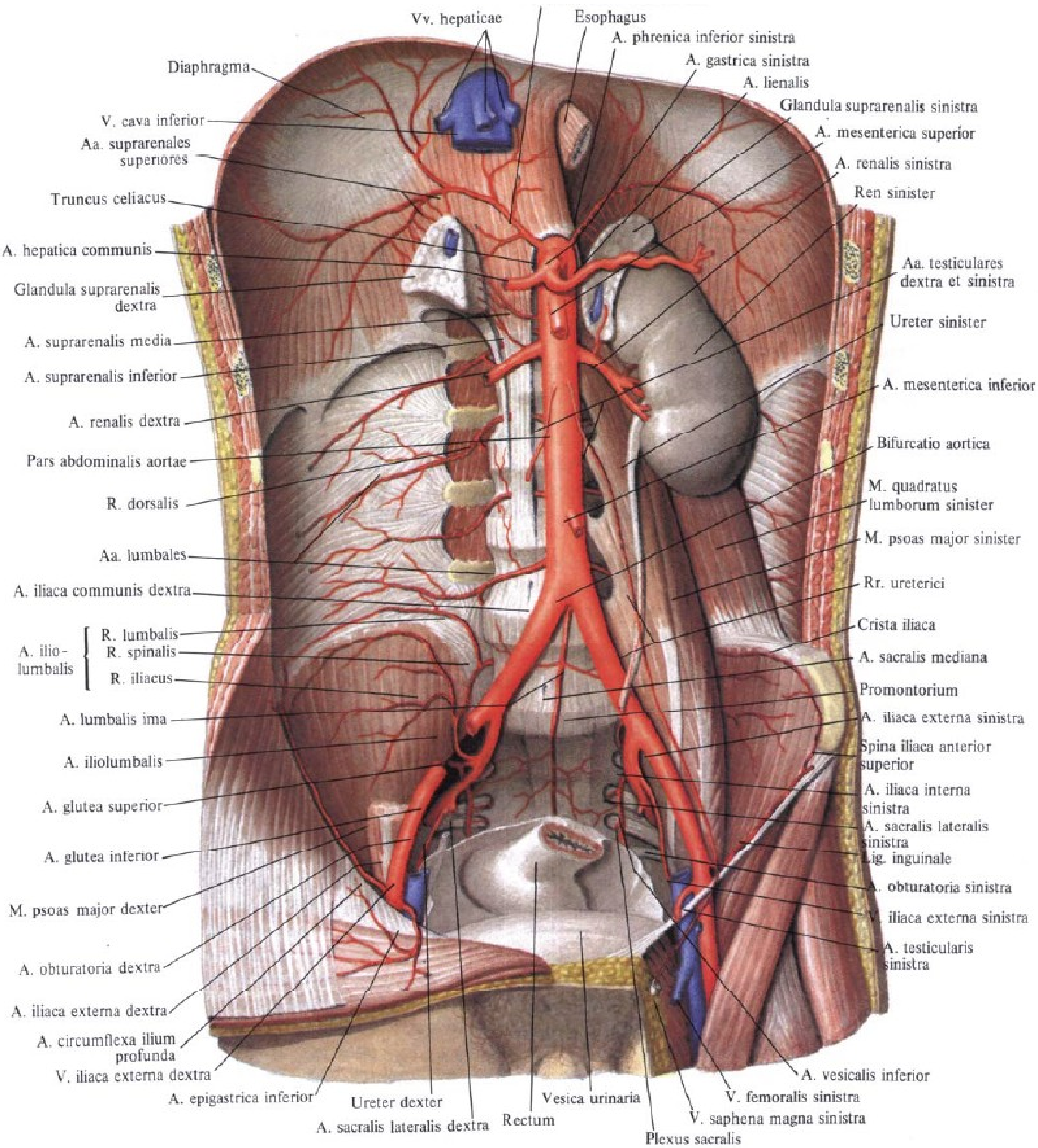

A. et v. transversae colli
M. supraspinatus
A. et v. suprascapulares
Lig. transversum scapulae superius
M. levator scapulae
M. trapezius
Spina scapulae
Rete acromiale
A. et v. suprascapulares
M. infraspinatus
M. rhomboideus
M. deltoideus
M. teres minor
Vascular network (anastomoses between aa. transversa colli, a. suprascapularis and circumflexa scapulae)
Foramen quadrilaterum
A. et v. circumflexae humeri posteriores
R. profundus a. transversae colli
A. et v. circumflexae scapulae
M. teres major
M. teres major
A. et v. profundae brachii
M. triceps brachii (caput laterale)
M. triceps brachii (caput longum)
N. radialis


M. brachialis
N. medianus
A. brachialis
A. collateralis ulnaris superior
N. ulnaris
M. biceps brachii
A. collateralis ulnaris inferior
A. brachialis
Epicondylus medialis
N. radialis (r. superficialis)
N. radialis (r. profundus)
M. brachialis
R. anterior
R. posterior
A. recurrens ulnaris
A. recurrens radialis
A. interossea communis
N. ulnaris
A. interossea posterior
A. ulnaris
A. interossea anterior
M. flexor carpi ulnaris
M. flexor digitorum profundus
A. radialis
M. flexor pollicis longus
M. pronator quadratus
R. carpalis palmaris a. radialis
Retinaculum flexorum
R. carpalis palmaris a. ulnaris
R. palmaris superficialis a. radialis
Os pisiforme
Arcus palmaris profundus
R. palmaris profundus a. ulnaris
A. princeps pollicis
M. adductor pollicis
Arcus palmaris superficialis
Ветви a. princeps pollicis
Aa. digitales palmares communes
A. radialis indicis
Aa. digitales palmares propriae

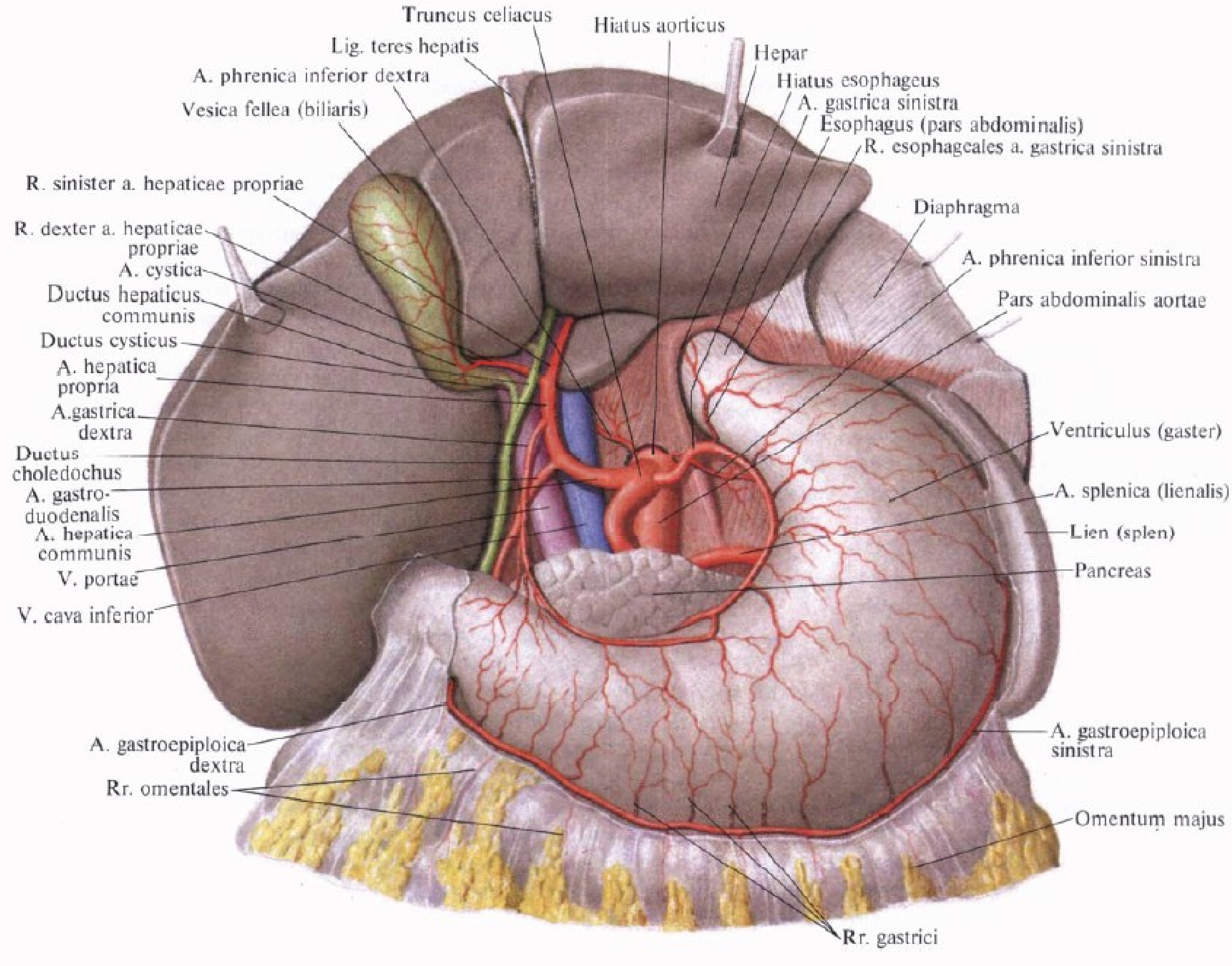

M. triceps brachii (tendo)
M. brachioradialis
Ветвь a. collateralis ulnaris superior
M. extensor carpi radialis longus
Ветвь a. collateralis ulnaris inferior
Анастомоз между a. interossea recurrens, a. collateralis media, a. collateralis radialis
Rete articulare cubiti
Rete articulare cubiti
Ветвь a. recurrens ulnaris
M. extensor digitorum communis
M. supinator
M. anconeus
A. interossea recurrens
R. profundus n. radialis
M. extensor carpi radialis brevis
A. interossea posterior
M. flexor carpi ulnaris
M. abductor pollicis longus
M. extensor pollicis brevis
A. interossea anterior
M. extensor pollicis longus
Tendines m. extensoris digitorum communis
M. extensor carpi ulnaris
M. extensor indicis proprius
Retinaculum extensorum
Rete carpale dorsale
A. radialis
R. carpalis dorsalis a. ulnaris
R. carpalis dorsalis a. radialis
A. metacarpalis dorsalis I
Mm. interossei dorsales
Aa. metacarpales dorsales
Ветви a. princeps pollicis
Aa. digitales dorsales

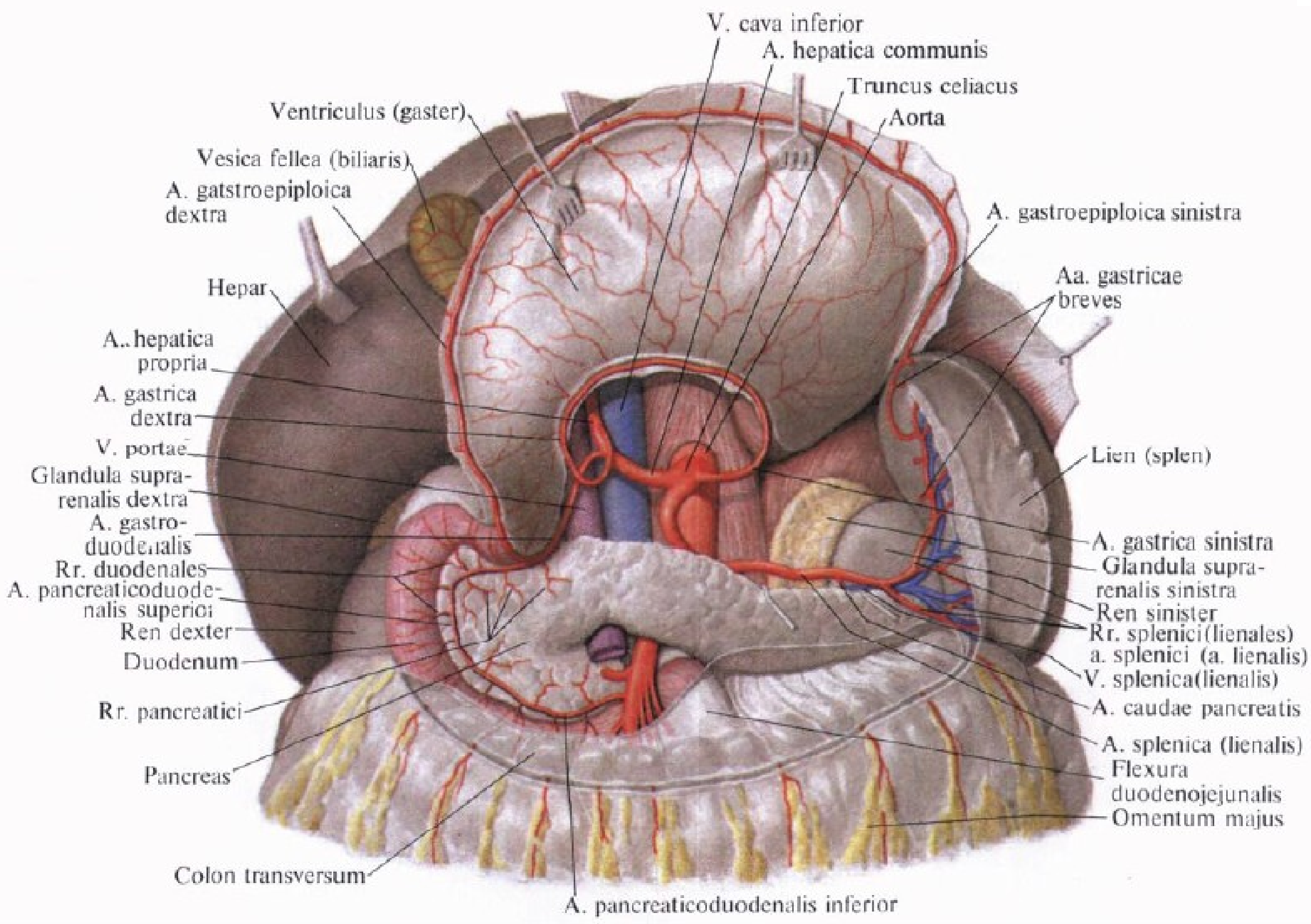


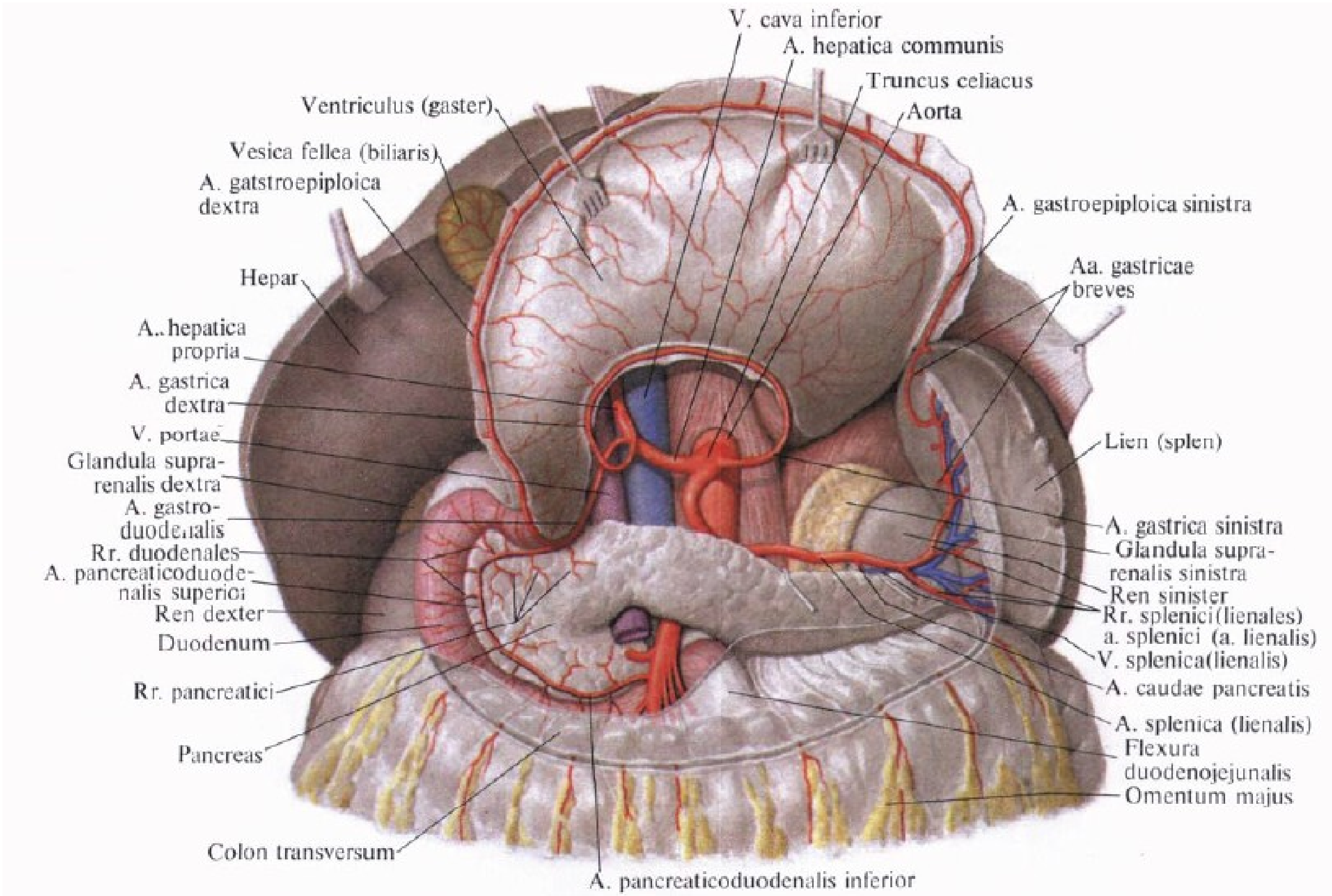
A. carotis communis dextra
A. vertebralis dextra
A. cervicalis ascendens
A. cervicalis superficialis
Truncus thyrocervicalis
A. subclavia dextra
A. suprascapularis
A. thoracica interna
A. transversa cervicis
Truncus brachiocephalicus
Pars ascendens aortae
Aa. coronariae cordis, dextra et sinistra
Valva aortae
Esophagus
Rr. esophageales
Aorta
Rr. dorsales aa. intercostales posteriores
A. gastrica sinistra
A. phrenica inferior dextra
A. hepatica communis
A. renalis dextra
A. mesenterica superior
A. thyroidea inferior
Trachea
A. carotis communis sinistra
A. subclavia sinistra
M. scalenus anterior
Plexus brachialis
Truncus costocervicalis
A. intercostalis suprema
Aa. intercostales posteriores I et II
Arcus aortae
Rr. bronchiales pars thoracicae aortae
Bronchus principalis sinister
Bulbus aortae
Rr. mediastinales
Rr. pericardiaci
Esophagus
Diaphragma
Ventriculus (pars cardiaca)
Rr. esophagealis
Truncus celiacus
A. splenica (lienalis)
A. renalis sinistra



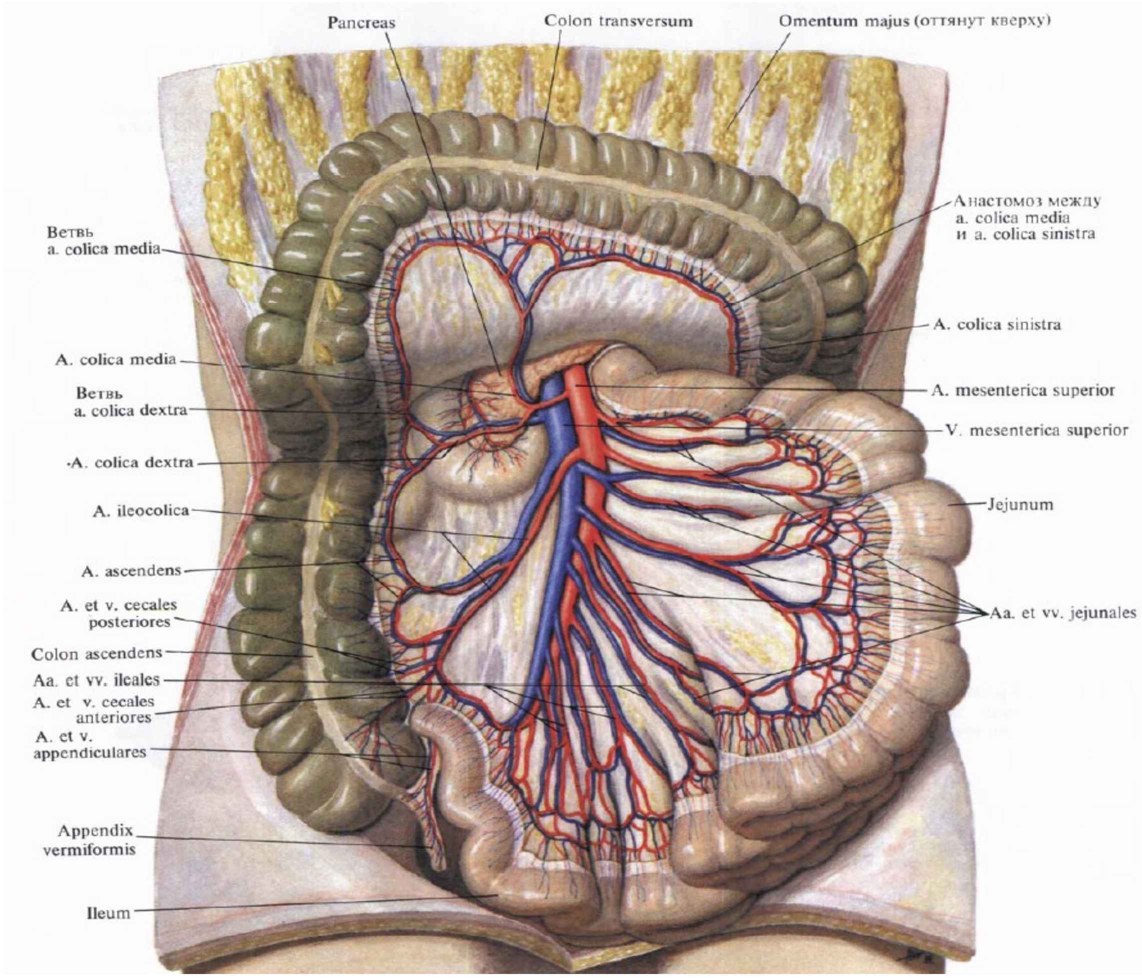
Vv. hepaticae
Esophagus
A. phrenica inferior sinistra
A. gastrica sinistra
A. lienalis
Glandula suprarenalis sinistra
A. mesenterica superior
A. renalis sinistra
Ren sinister
Aa. testiculares dextra et sinistra
Ureter sinister
A. mesenterica inferior
Bifurcatio aortica
M. quadratus lumborum sinister
M. psoas major sinister
Rr. ureterici
Crista iliaca
A. sacralis mediana
Promontorium
A. iliaca externa sinistra
Spina iliaca anterior superior
A. iliaca interna sinistra
A. sacralis lateralis sinistra
Lig. inguinale
A. obturatoria sinistra
V. iliaca externa sinistra
A. testicularis sinistra
A. vesicalis inferior
V. femoralis sinistra
V. saphena magna sinistra
Plexus sacralis
Vesica urinaria
Rectum
A. sacralis lateralis dextra
Ureter dexter
A. epigastrica inferior
V. iliaca externa dextra
A. circumflexa ilium profunda
A. iliaca externa dextra
A. obturatoria dextra
M. psoas major dexter
A. glutea inferior
A. glutea superior
A. iliolumbalis
A. lumbalis ima
A. ilio-lumbalis
R. lumbalis
R. spinalis
R. iliacus
A. iliaca communis dextra
Aa. lumbales
R. dorsalis
Pars abdominalis aortae
A. renalis dextra
A. suprarenalis inferior
A. suprarenalis media
Glandula suprarenalis dextra
A. hepatica communis
Truncus celiacus
Aa. suprarenales superiores
V. cava inferior
Diaphragma


Truncus celiacus
Hiatus aorticus
Lig. teres hepatis
Hepar
A. phrenica inferior dextra
Hiatus esophageus
Vesica fellea (biliaris)
A. gastrica sinistra
Esophagus (pars abdominalis)
R. esophageales a. gastrica sinistra
R. sinister a. hepaticae propriae
Diaphragma
R. dexter a. hepaticae propriae
A. phrenica inferior sinistra
A. cystica
Ductus hepaticus communis
Pars abdominalis aortae
Ductus cysticus
A. hepatica propria
A.gastrica dextra
Ventriculus (gaster)
Ductus choledochus
A. gastro-duodenalis
A. splenica (lienalis)
A. hepatica communis
Lien (splen)
V. portae
Pancreas
V. cava inferior
A. gastroepiploica dextra
A. gastroepiploica sinistra
Rr. omentales
Omentum majus
Rr. gastrici

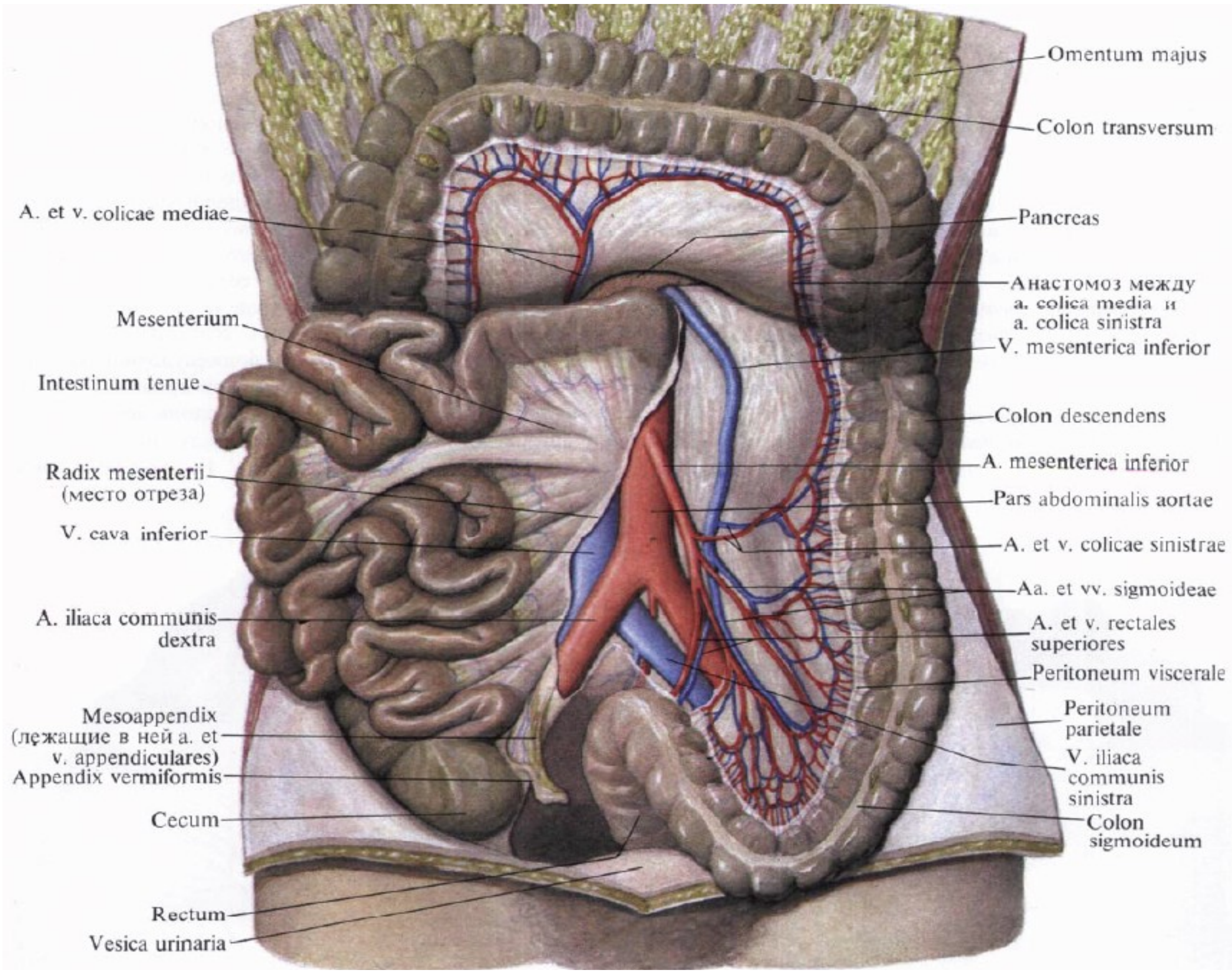

V. cava inferior
A. hepatica communis
Truncus celiacus
Ventriculus (gaster)
Aorta
Vesica fellea (biliaris)
A. gatstroepiploica dextra
A. gastroepiploica sinistra
Hepar
Aa. gastricae breves
A.. hepatica propria
A. gastrica dextra
V. portae
Lien (splen)
Glandula supra-renalis dextra
A. gastro-duodenalis
A. gastrica sinistra
Glandula supra-renalis sinistra
Rr. duodenales
A. pancreaticoduode-nalis superior
Ren sinister
Ren dexter
Rr. splenici (lienales) a. splenici (a. lienalis)
Duodenum
V. splenica(lienalis)
Rr. pancreatici
A. caudae pancreatis
A. splenica (lienalis)
Pancreas
Flexura duodenojejunalis
Omentum majus
Colon transversum
A. pancreaticoduodenalis inferior

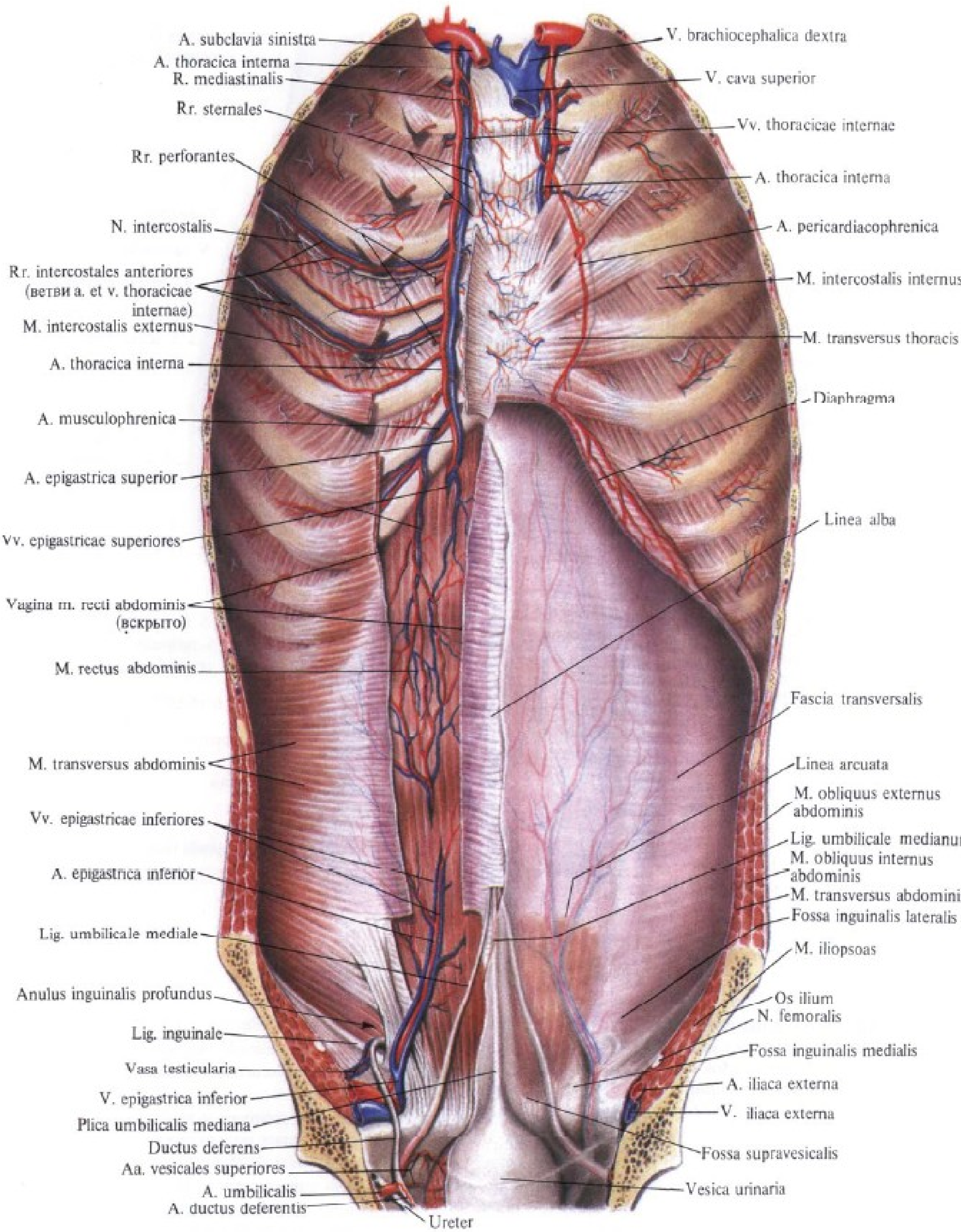


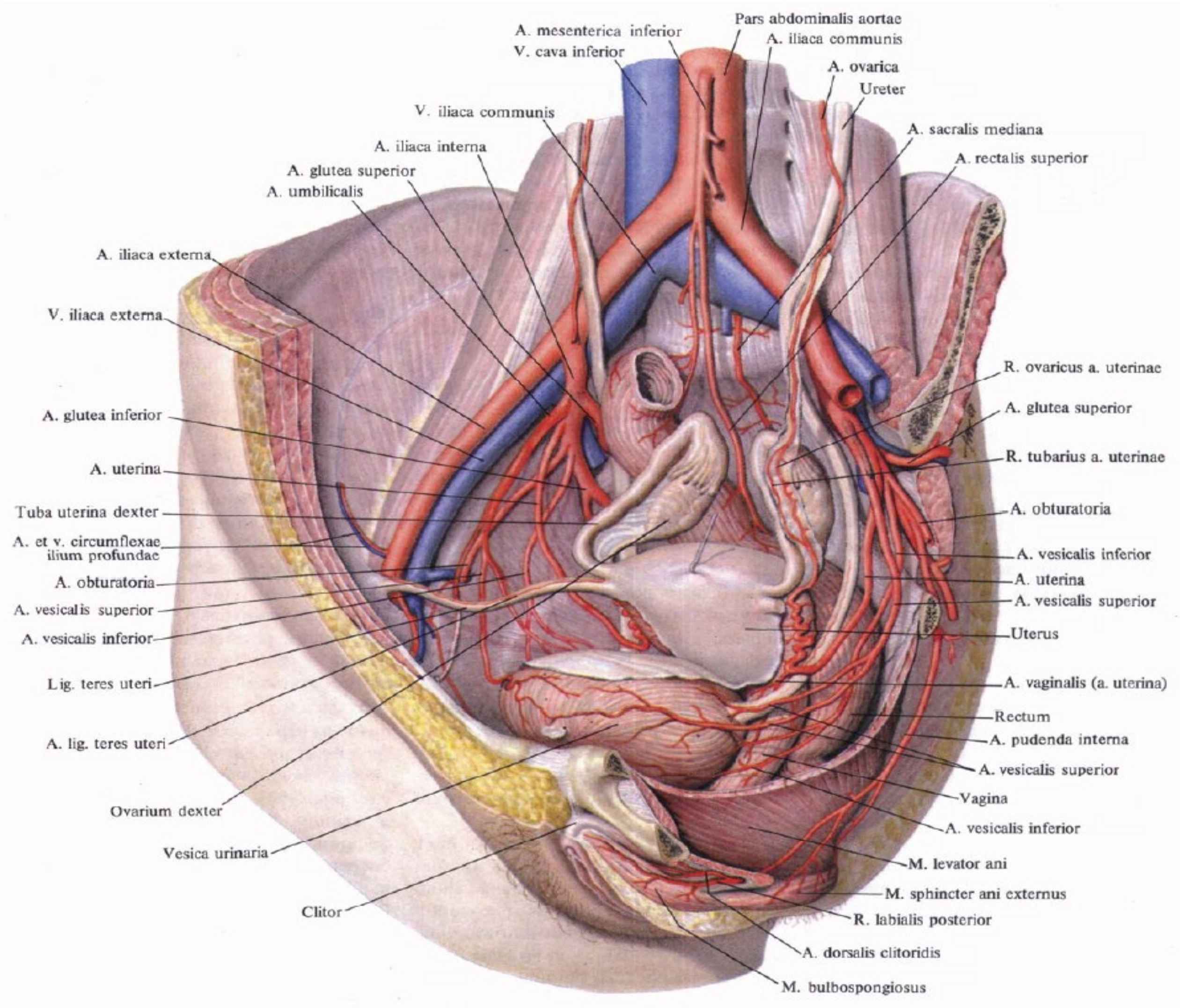
V. cava inferior
A. hepatica communis
Truncus celiacus
Aorta
Ventriculus (gaster)
Vesica fellea (biliaris)
A. gatstroepiploica dextra
Hepar
A. hepatica propria
A. gastrica dextra
V. portae
Glandula suprarenalis dextra
A. gastroduodenalis
Rr. duodenales
A. pancreaticoduodenalis superior
Ren dexter
Duodenum
Rr. pancreatici
Pancreas
Colon transversum
A. pancreaticoduodenalis inferior
A. gastroepiploica sinistra
Aa. gastricae breves
Lien (splen)
A. gastrica sinistra
Glandula suprarenalis sinistra
Ren sinister
Rr. splenici (lienales) a. splenici (a. lienalis)
V. splenica (lienalis)
A. caudae pancreatis
A. splenica (lienalis)
Flexura duodenojejunalis
Omentum majus

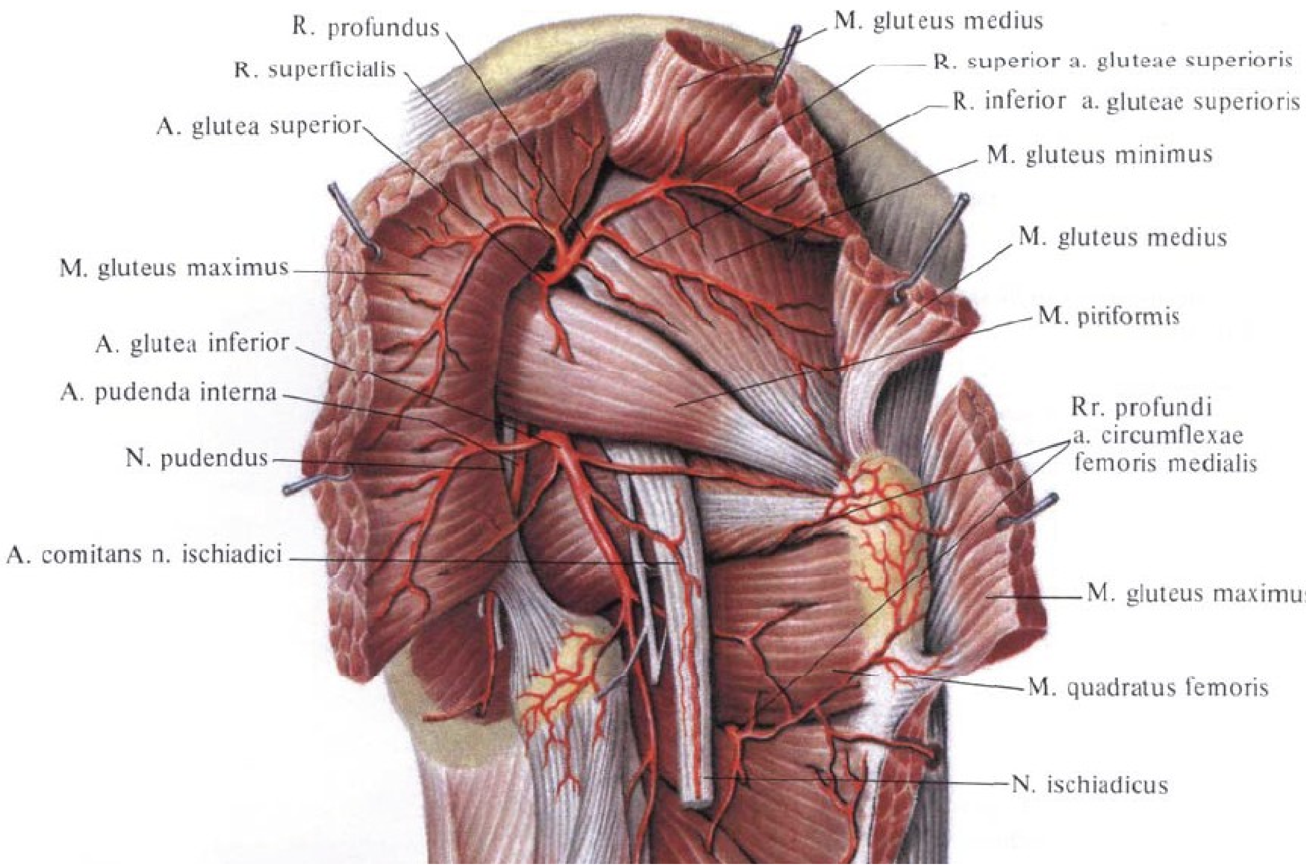


Pancreas
Colon transversum
Omentum majus (оттянут кверху)
Анастомоз между
a. colica media
и a. colica sinistra
Ветвь
a. colica media
A. colica sinistra
A. colica media
A. mesenterica superior
Ветвь
a. colica dextra
V. mesenterica superior
A. colica dextra
A. ileocolica
Jejunum
A. ascendens
A. et v. cecales
posteriores
Aa. et vv. jejunales
Colon ascendens
Aa. et vv. ileales
A. et v. cecales
anteriores
A. et v.
appendiculares
Appendix
vermiformis
Ileum

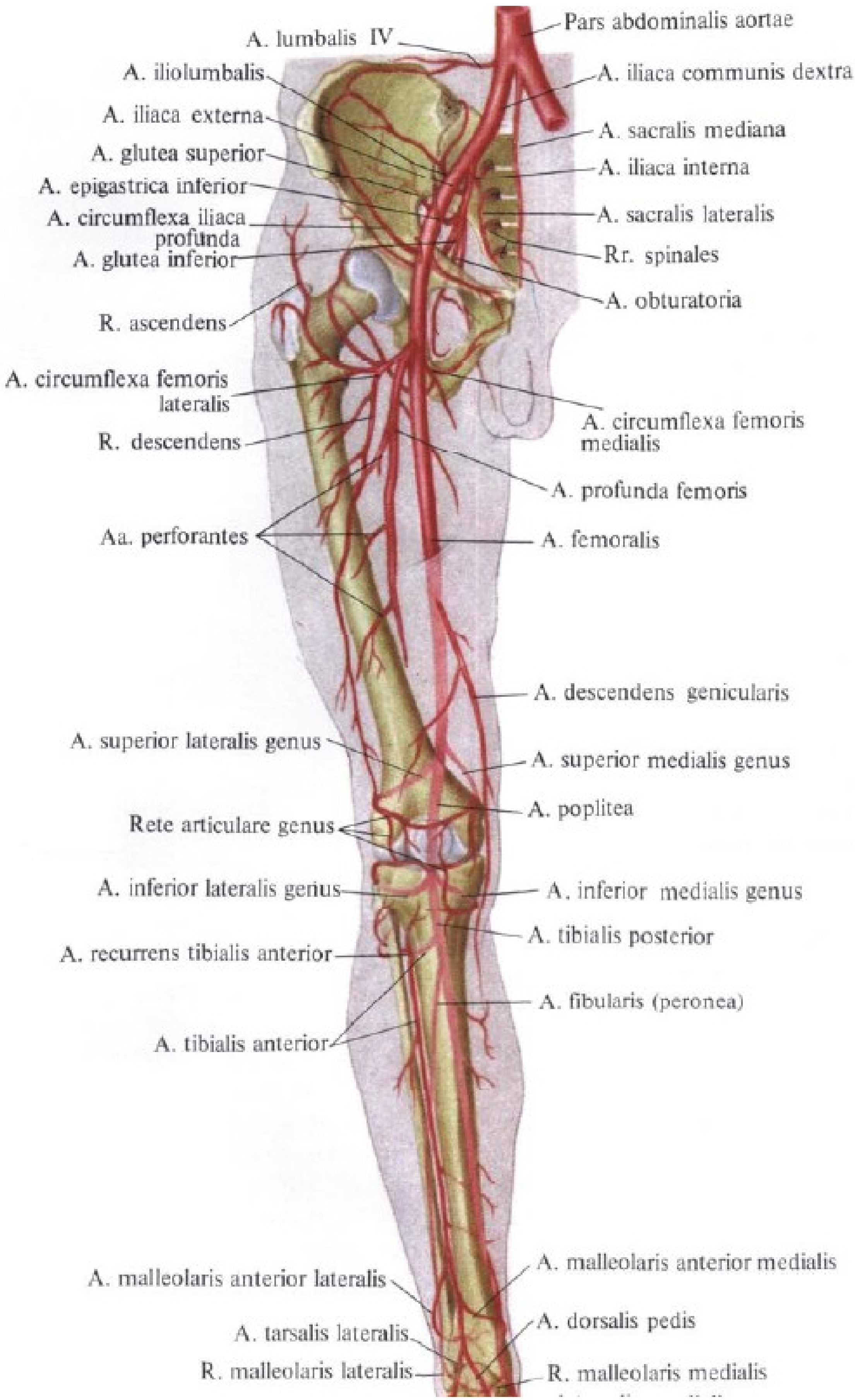

Omentum majus
Colon transversum
A. et v. colicae mediae
Pancreas
Анастомоз между
a. colica media и
a. colica sinistra
Mesenterium
V. mesenterica inferior
Intestinum tenue
Colon descendens
A. mesenterica inferior
Radix mesenterii
(место отреза)
Pars abdominalis aortae
V. cava inferior
A. et v. colicae sinistrae
Aa. et vv. sigmoideae
A. iliaca communis
dextra
A. et v. rectales
superiores
Peritoneum viscerale
Mesoappendix
(лежащие в ней a. et
v. appendiculares)
Peritoneum
parietale
Appendix vermiformis
V. iliaca
communis
sinistra
Cecum
Colon
sigmoideum
Rectum
Vesica urinaria

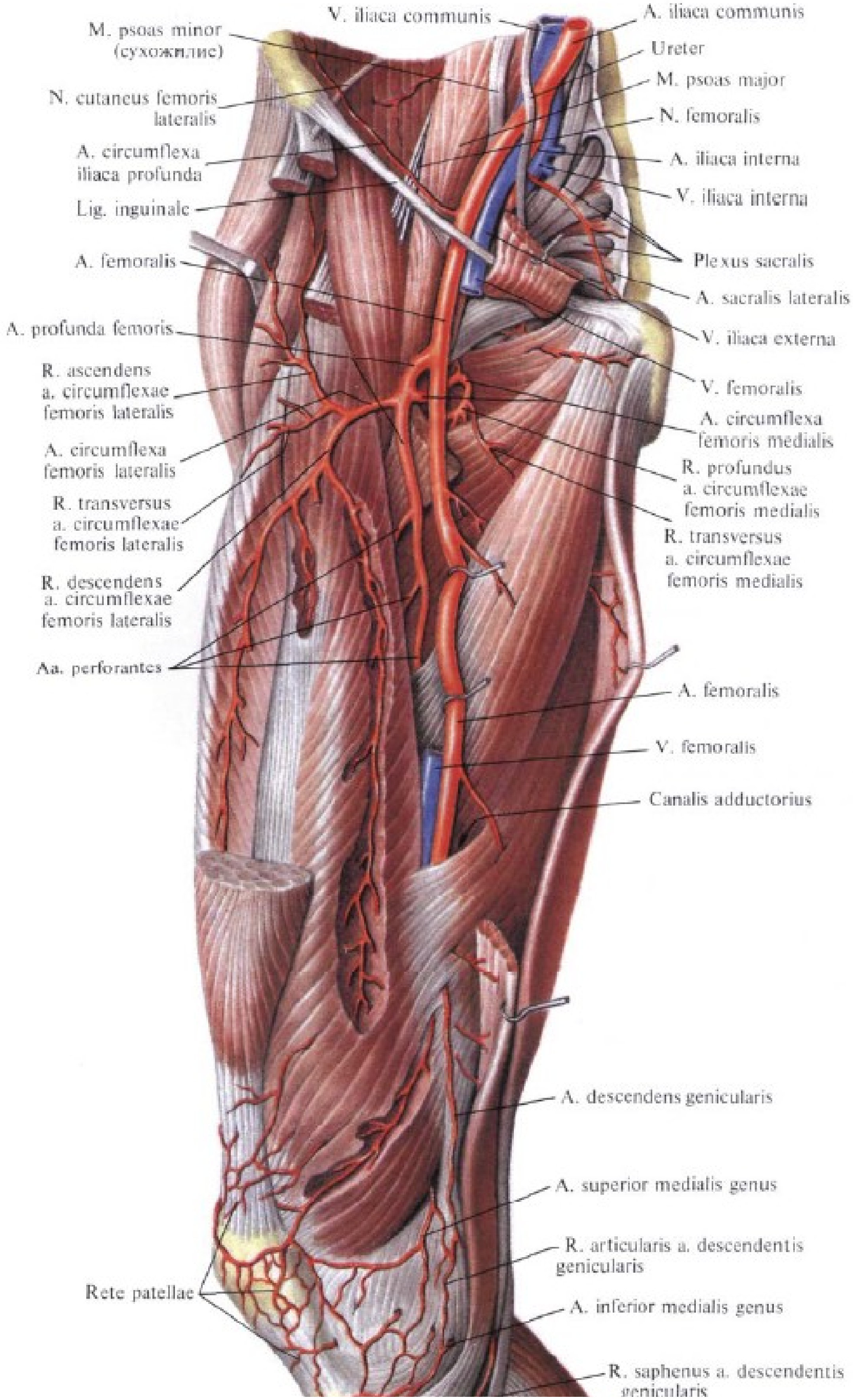

A. subclavia sinistra
A. thoracica interna
R. mediastinalis
Rr. sternales
Rr. perforantes
N. intercostalis
Rr. intercostales anteriores (ветви a. et v. thoracicae internae)
M. intercostalis externus
A. thoracica interna
A. musculophrenica
A. epigastrica superior
Vv. epigastricae superiores
Vagina m. recti abdominis (вскрыто)
M. rectus abdominis
M. transversus abdominis
Vv. epigastricae inferiores
A. epigastrica inferior
Lig. umbilicale mediale
Anulus inguinalis profundus
Lig. inguinale
Vasa testicularia
V. epigastrica inferior
Plica umbilicalis mediana
Ductus deferens
Aa. vesicales superiores
A. umbilicalis
A. ductus deferentis
Ureter
V. brachiocephalica dextra
V. cava superior
Vv. thoracicae internae
A. thoracica interna
A. pericardiacophrenica
M. intercostalis internus
M. transversus thoracis
Diaphragma
Linea alba
Fascia transversalis
Linea arcuata
M. obliquus externus abdominis
Lig. umbilicale medianum
M. obliquus internus abdominis
M. transversus abdominis
Fossa inguinalis lateralis
M. iliopsoas
Os ilium
N. femoralis
Fossa inguinalis medialis
A. iliaca externa
V. iliaca externa
Fossa supravesicalis
Vesica urinaria

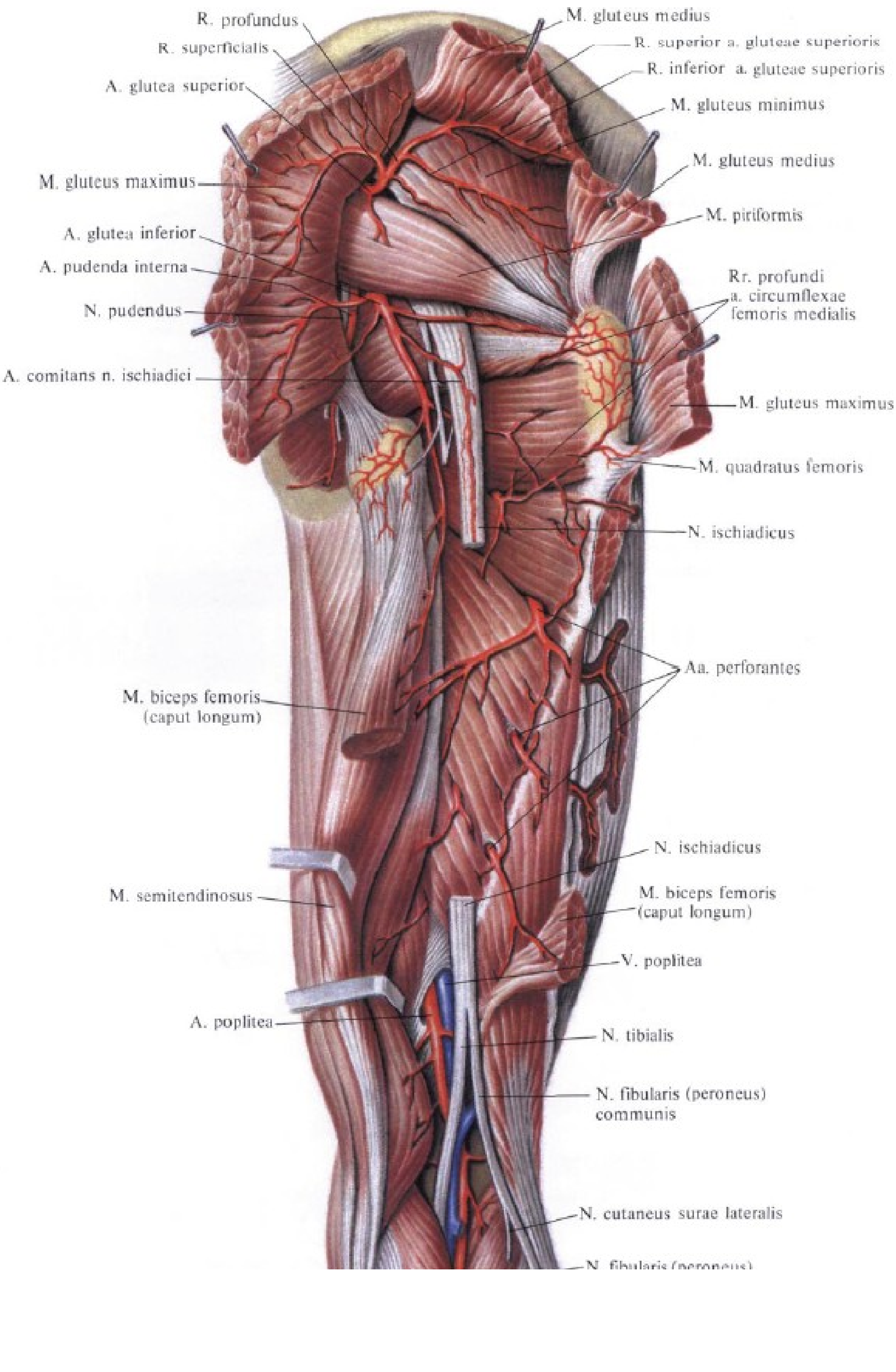

A. mesenterica inferior
V. cava inferior
Pars abdominalis aortae
A. iliaca communis
A. ovarica
Ureter
V. iliaca communis
A. sacralis mediana
A. rectalis superior
A. iliaca interna
A. glutea superior
A. umbilicalis
A. iliaca externa
V. iliaca externa
R. ovaricus a. uterinae
A. glutea superior
A. glutea inferior
R. tubarius a. uterinae
A. uterina
A. obturatoria
Tuba uterina dexter
A. et v. circumflexae ilium profundae
A. vesicalis inferior
A. obturatoria
A. uterina
A. vesicalis superior
A. vesicalis superior
Uterus
A. vesicalis inferior
Lig. teres uteri
A. vaginalis (a. uterina)
Rectum
A. pudenda interna
A. lig. teres uteri
A. vesicalis superior
Vagina
Ovarium dexter
A. vesicalis inferior
Vesica urinaria
M. levator ani
M. sphincter ani externus
Clitor
R. labialis posterior
A. dorsalis clitoridis
M. bulbospongiosus

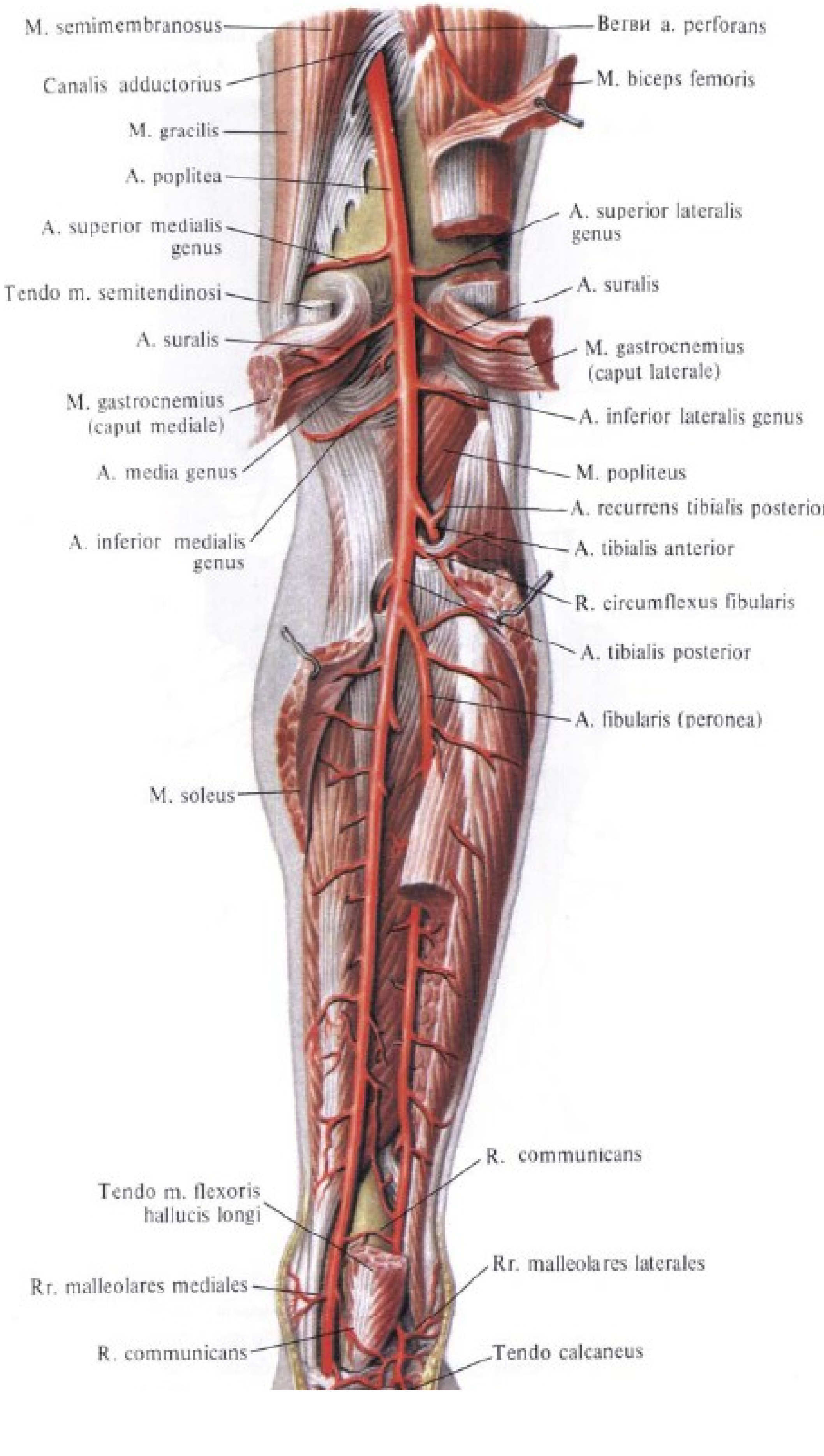


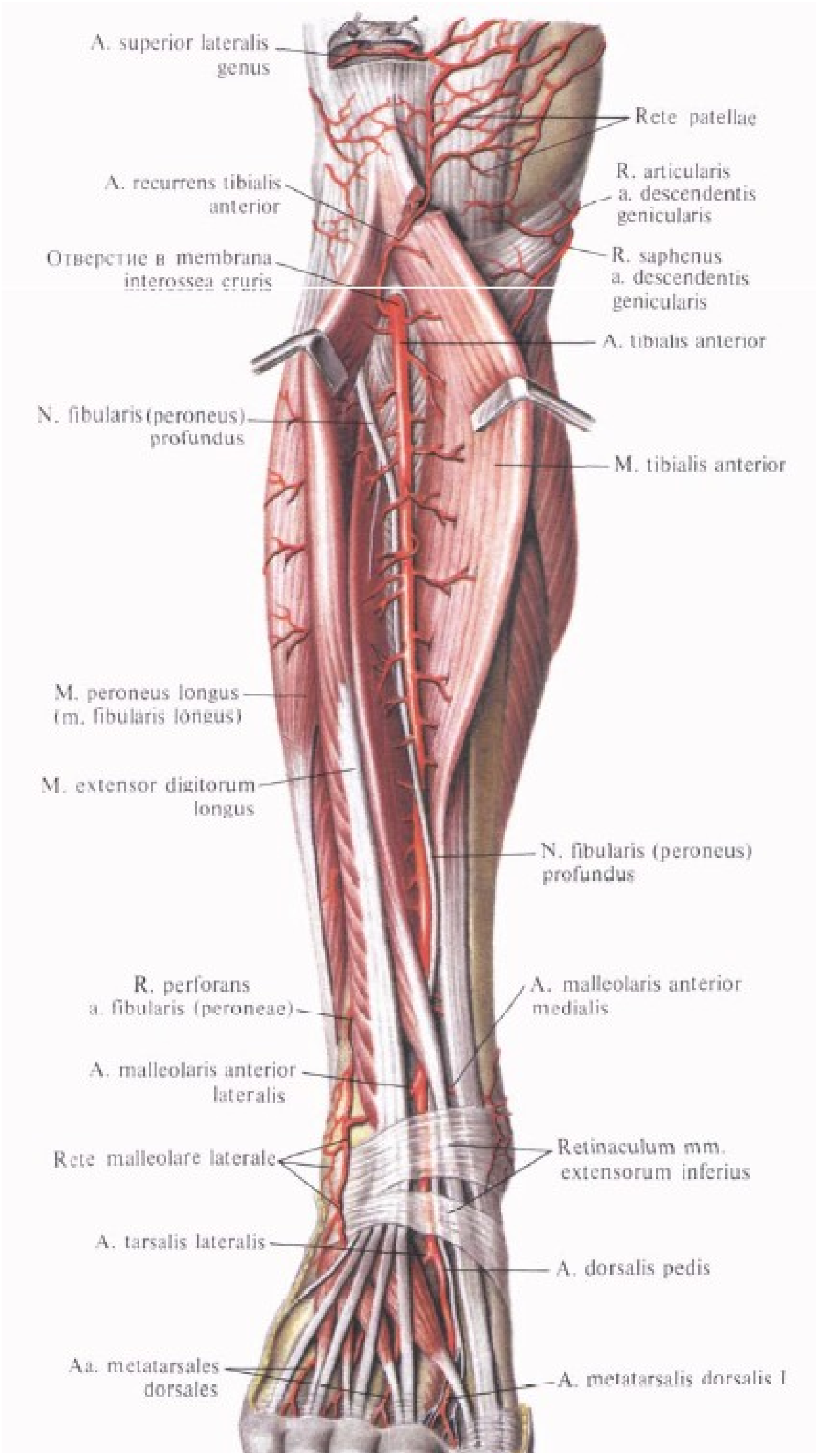
R. profundus
R. superficialis
A. glutea superior
M. gluteus maximus
A. glutea inferior
A. pudenda interna
N. pudendus
A. comitans n. ischiadici
M. gluteus medius
R. superior a. gluteae superioris
R. inferior a. gluteae superioris
M. gluteus minimus
M. gluteus medius
M. piriformis
Rr. profundi
a. circumflexae
femoris medialis
M. gluteus maximus
M. quadratus femoris
N. ischiadicus


Pars abdominalis aortae
A. lumbalis IV
A. iliolumbalis
A. iliaca communis dextra
A. iliaca externa
A. sacralis mediana
A. glutea superior
A. iliaca interna
A. epigastrica inferior
A. circumflexa iliaca profunda
A. sacralis lateralis
A. glutea inferior
Rr. spinales
A. obturatoria
R. ascendens
A. circumflexa femoris lateralis
A. circumflexa femoris medialis
R. descendens
A. profunda femoris
Aa. perforantes
A. femoralis
A. descendens genicularis
A. superior lateralis genus
A. superior medialis genus
A. poplitea
Rete articulare genus
A. inferior lateralis genus
A. inferior medialis genus
A. tibialis posterior
A. recurrens tibialis anterior
A. fibularis (peronea)
A. tibialis anterior
A. malleolaris anterior medialis
A. malleolaris anterior lateralis
A. dorsalis pedis
A. tarsalis lateralis
R. malleolaris lateralis
R. malleolaris medialis

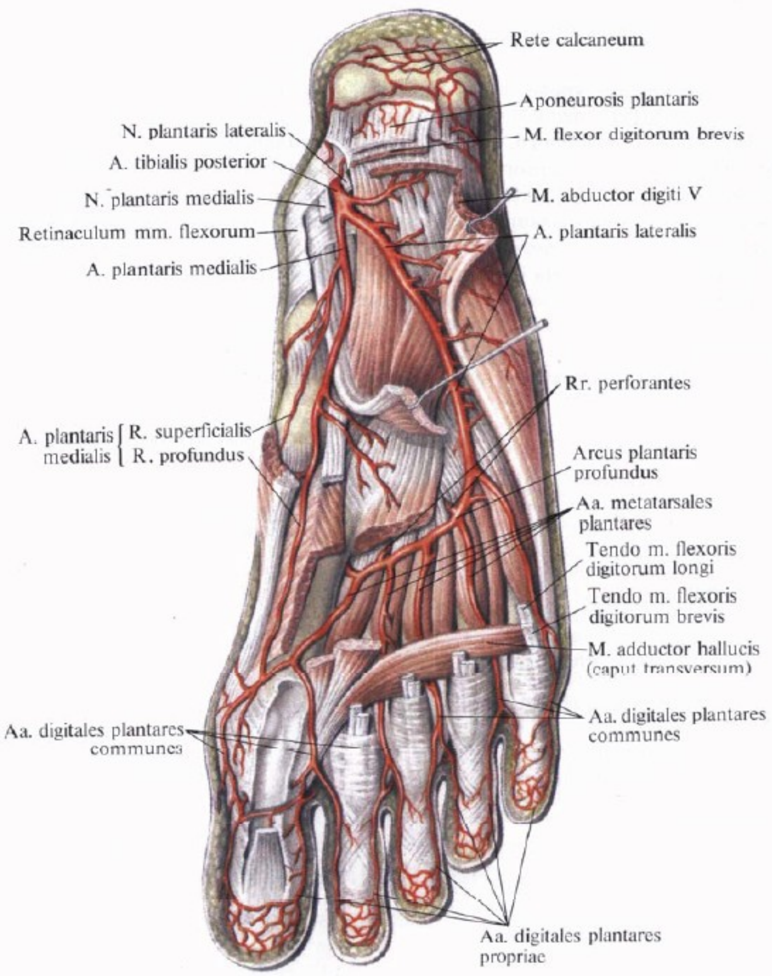

V. iliaca communis
A. iliaca communis
M. psoas minor (сухожилие)
Ureter
M. psoas major
N. cutaneus femoris lateralis
N. femoralis
A. circumflexa iliaca profunda
A. iliaca interna
V. iliaca interna
Lig. inguinale
Plexus sacralis
A. femoralis
A. sacralis lateralis
A. profunda femoris
V. iliaca externa
R. ascendens a. circumflexae femoris lateralis
V. femoralis
A. circumflexa femoris medialis
A. circumflexa femoris lateralis
R. profundus a. circumflexae femoris medialis
R. transversus a. circumflexae femoris lateralis
R. transversus a. circumflexae femoris medialis
R. descendens a. circumflexae femoris lateralis
Aa. perforantes
A. femoralis
V. femoralis
Canalis adductorius
A. descendens genicularis
A. superior medialis genus
R. articularis a. descendentis genicularis
Rete patellae
A. inferior medialis genus
R. saphenus a. descendentis genicularis


R. profundus
R. superficialis
A. glutea superior
M. gluteus maximus
A. glutea inferior
A. pudenda interna
N. pudendus
A. comitans n. ischiadici
M. gluteus medius
R. superior a. gluteae superioris
R. inferior a. gluteae superioris
M. gluteus minimus
M. gluteus medius
M. piriformis
Rr. profundi
a. circumflexae
femoris medialis
M. gluteus maximus
M. quadratus femoris
N. ischiadicus
Aa. perforantes
M. biceps femoris
(caput longum)
N. ischiadicus
M. semitendinosus
M. biceps femoris
(caput longum)
V. poplitea
A. poplitea
N. tibialis
N. fibularis (peroneus)
communis
N. cutaneus surae lateralis

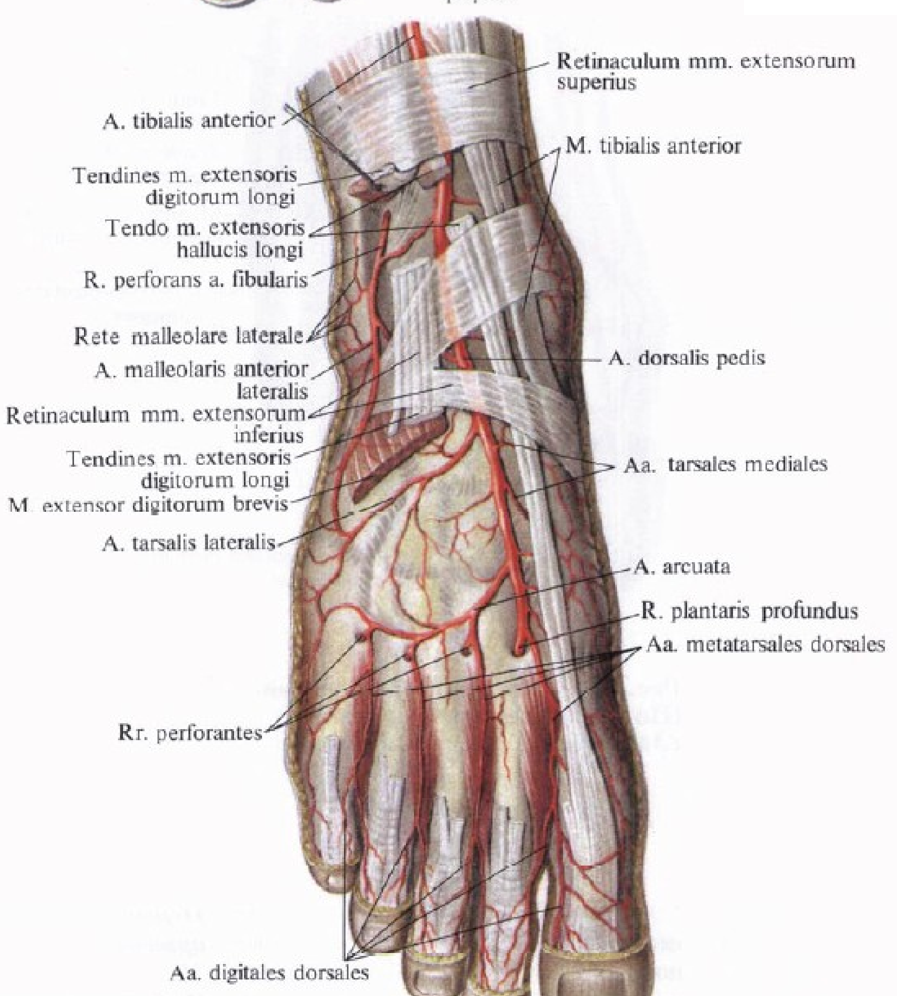

M. semimembranosus
Ветви a. perforans
Canalis adductorius
M. biceps femoris
M. gracilis
A. poplitea
A. superior medialis genus
A. superior lateralis genus
Tendo m. semitendinosi
A. suralis
A. suralis
M. gastrocnemius (caput laterale)
M. gastrocnemius (caput mediale)
A. inferior lateralis genus
A. media genus
M. popliteus
A. recurrens tibialis posterior
A. inferior medialis genus
A. tibialis anterior
R. circumflexus fibularis
A. tibialis posterior
A. fibularis (peronea)
M. soleus
R. communicans
Tendo m. flexoris hallucis longi
Rr. malleolares laterales
Rr. malleolares mediales
R. communicans
Tendo calcaneus



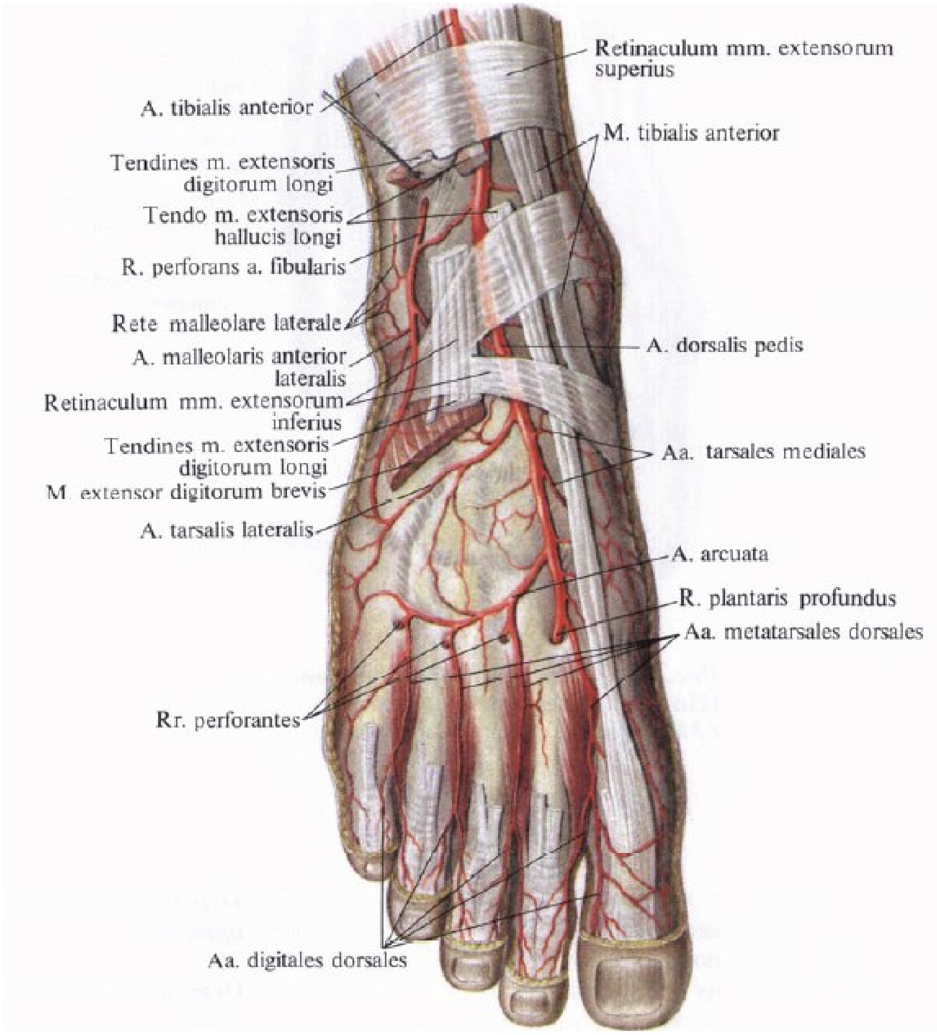
A. superior lateralis genus
Rete patellae
R. articularis a. descendentis genicularis
A. recurrens tibialis anterior
R. saphenus a. descendentis genicularis
Отверстие в membrana interossea cruris
A. tibialis anterior
N. fibularis (peroneus) profundus
M. tibialis anterior
M. peroneus longus (m. fibularis longus)
M. extensor digitorum longus
N. fibularis (peroneus) profundus
R. perforans a. fibularis (peroneae)
A. malleolaris anterior medialis
A. malleolaris anterior lateralis
Rete malleolare laterale
Retinaculum mm. extensorum inferius
A. tarsalis lateralis
A. dorsalis pedis
Aa. metatarsales dorsales
A. metatarsalis dorsalis I



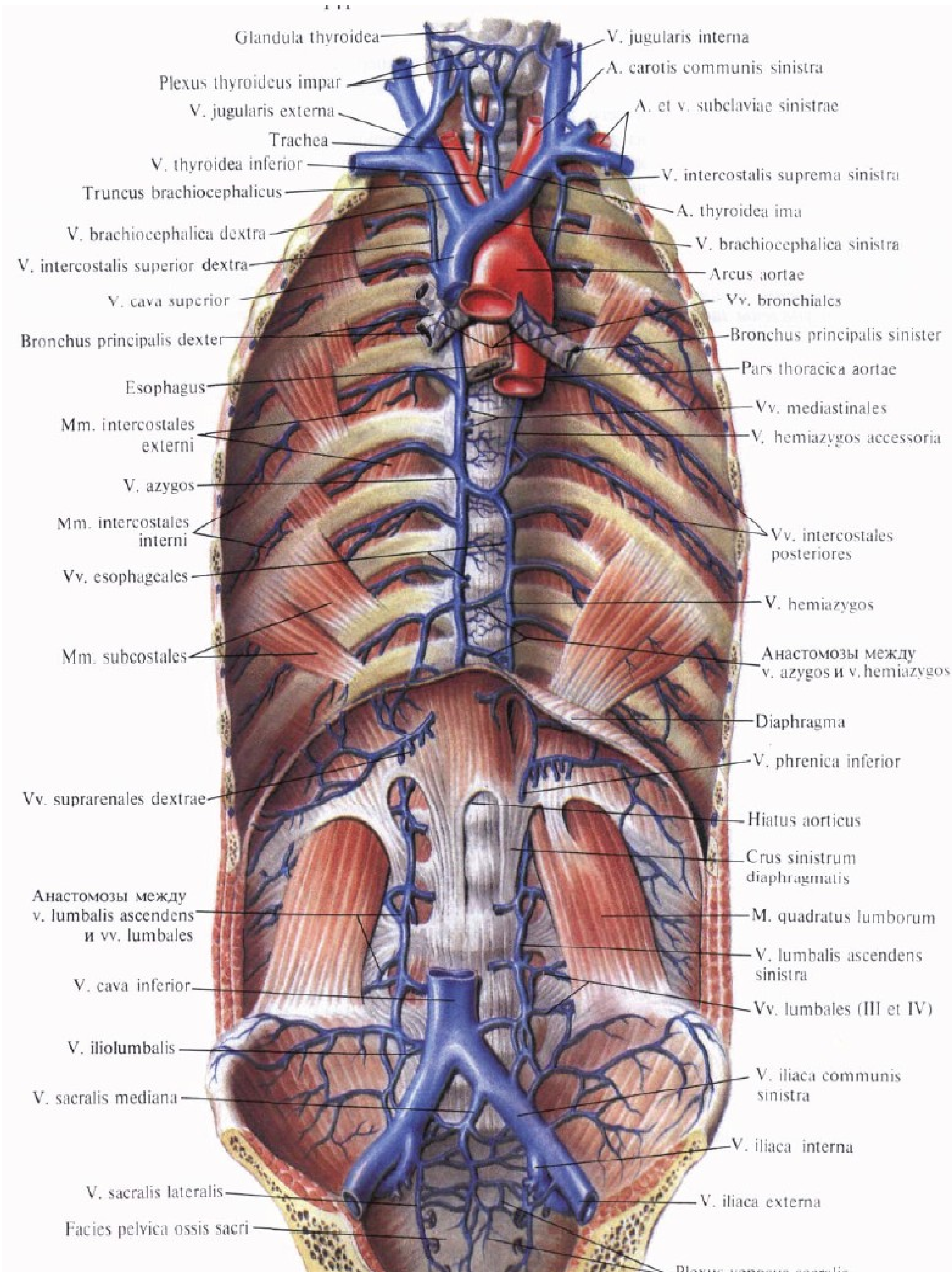
Rete calcaneum
Aponeurosis plantaris
N. plantaris lateralis
M. flexor digitorum brevis
A. tibialis posterior
N. plantaris medialis
M. abductor digiti V
Retinaculum mm. flexorum
A. plantaris lateralis
A. plantaris medialis
Rr. perforantes
A. plantaris medialis R. superficialis
R. profundus
Arcus plantaris profundus
Aa. metatarsales plantares
Tendo m. flexoris digitorum longi
Tendo m. flexoris digitorum brevis
M. adductor hallucis (caput transversum)
Aa. digitales plantares communes
Aa. digitales plantares communes
Aa. digitales plantares propriae



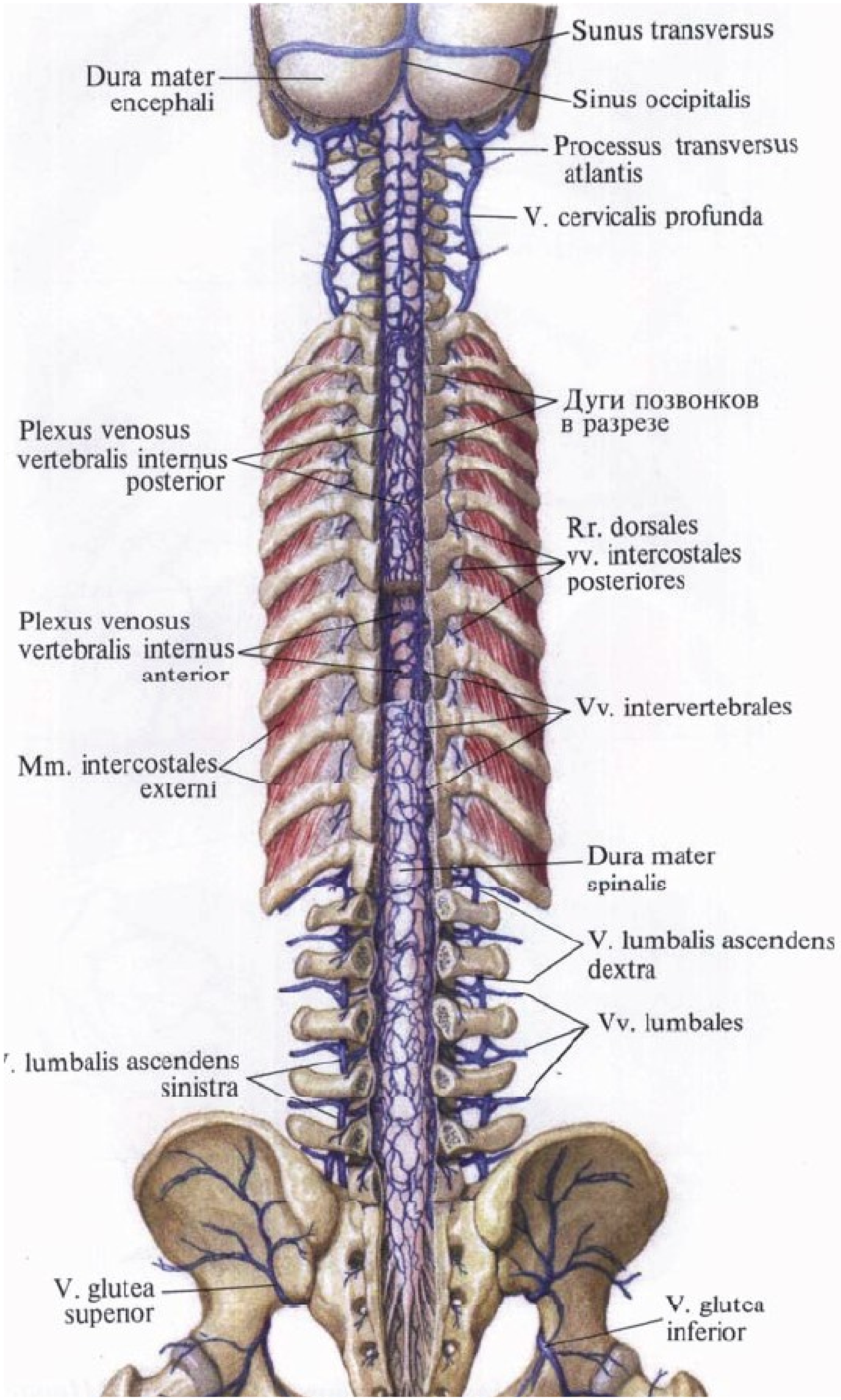
Retinaculum mm. extensorum superius
A. tibialis anterior
M. tibialis anterior
Tendines m. extensoris digitorum longi
Tendo m. extensoris hallucis longi
R. perforans a. fibularis
Rete malleolare laterale
A. dorsalis pedis
A. malleolaris anterior lateralis
Retinaculum mm. extensorum inferius
Tendines m. extensoris digitorum longi
Aa. tarsales mediales
M. extensor digitorum brevis
A. tarsalis lateralis
A. arcuata
R. plantaris profundus
Aa. metatarsales dorsales
Rr. perforantes
Aa. digitales dorsales



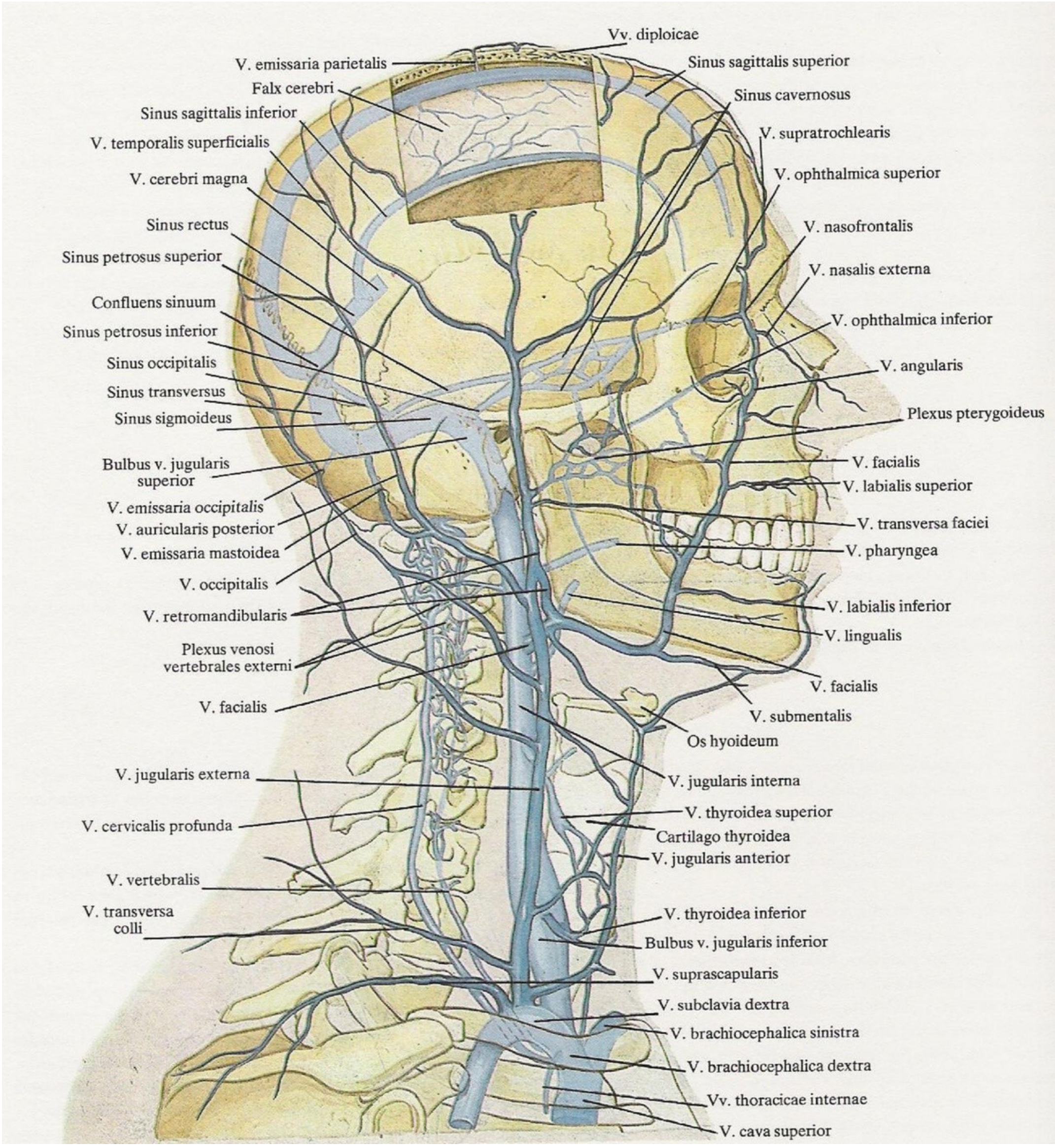
Retinaculum mm. extensorum superius
A. tibialis anterior
M. tibialis anterior
Tendines m. extensoris digitorum longi
Tendo m. extensoris hallucis longi
R. perforans a. fibularis
Rete malleolare laterale
A. malleolaris anterior lateralis
A. dorsalis pedis
Retinaculum mm. extensorum inferius
Tendines m. extensoris digitorum longi
Aa. tarsales mediales
M. extensor digitorum brevis
A. tarsalis lateralis
A. arcuata
R. plantaris profundus
Aa. metatarsales dorsales
Rr. perforantes
Aa. digitales dorsales



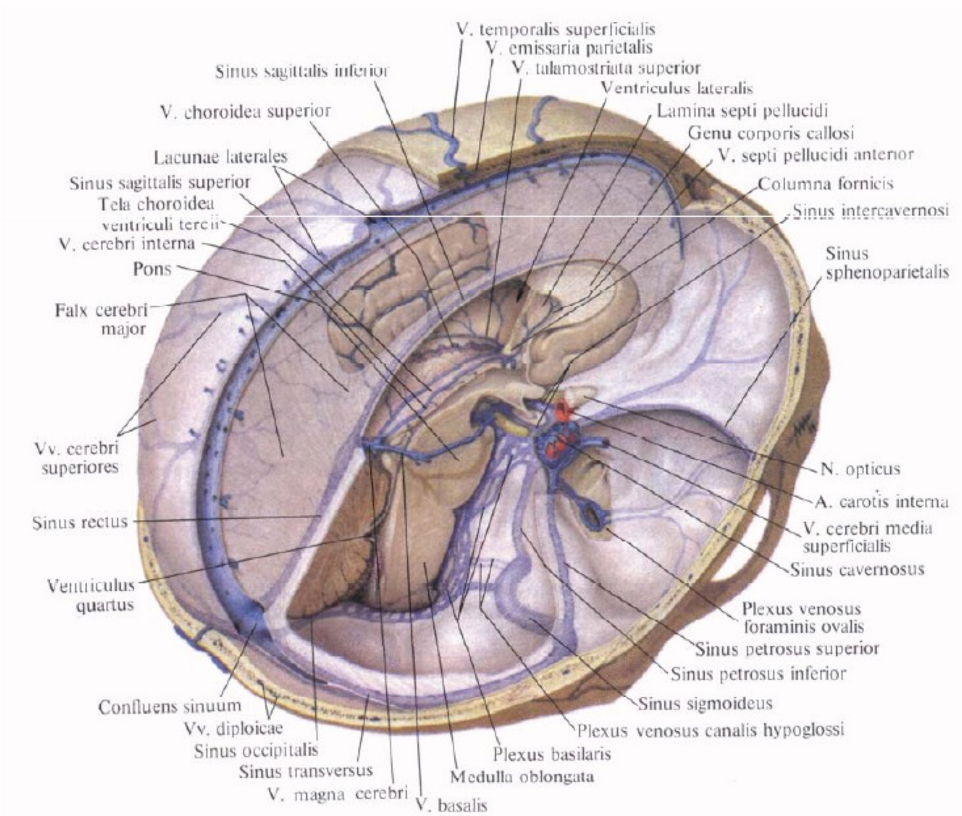
Glandula thyroidea
V. jugularis interna
Plexus thyroideus impar
A. carotis communis sinistra
V. jugularis externa
A. et v. subclaviae sinistrae
Trachea
V. thyroidea inferior
V. intercostalis suprema sinistra
Truncus brachiocephalicus
A. thyroidea ima
V. brachiocephalica dextra
V. brachiocephalica sinistra
V. intercostalis superior dextra
Arcus aortae
V. cava superior
Vv. bronchiales
Bronchus principalis dexter
Bronchus principalis sinister
Esophagus
Pars thoracica aortae
Vv. mediastinales
Mm. intercostales externi
V. hemiazygos accessoria
V. azygos
Mm. intercostales interni
Vv. intercostales posteriores
Vv. esophageales
V. hemiazygos
Mm. subcostales
Анастомозы между v. azygos и v. hemiazygos
Diaphragma
V. phrenica inferior
Vv. suprarenales dextrae
Hiatus aorticus
Crus sinistrum diaphragmatis
Анастомозы между v. lumbalis ascendens и vv. lumbales
M. quadratus lumborum
V. lumbalis ascendens sinistra
V. cava inferior
Vv. lumbales (III et IV)
V. iliolumbalis
V. iliaca communis sinistra
V. sacralis mediana
V. iliaca interna
V. sacralis lateralis
V. iliaca externa
Facies pelvica ossis sacri



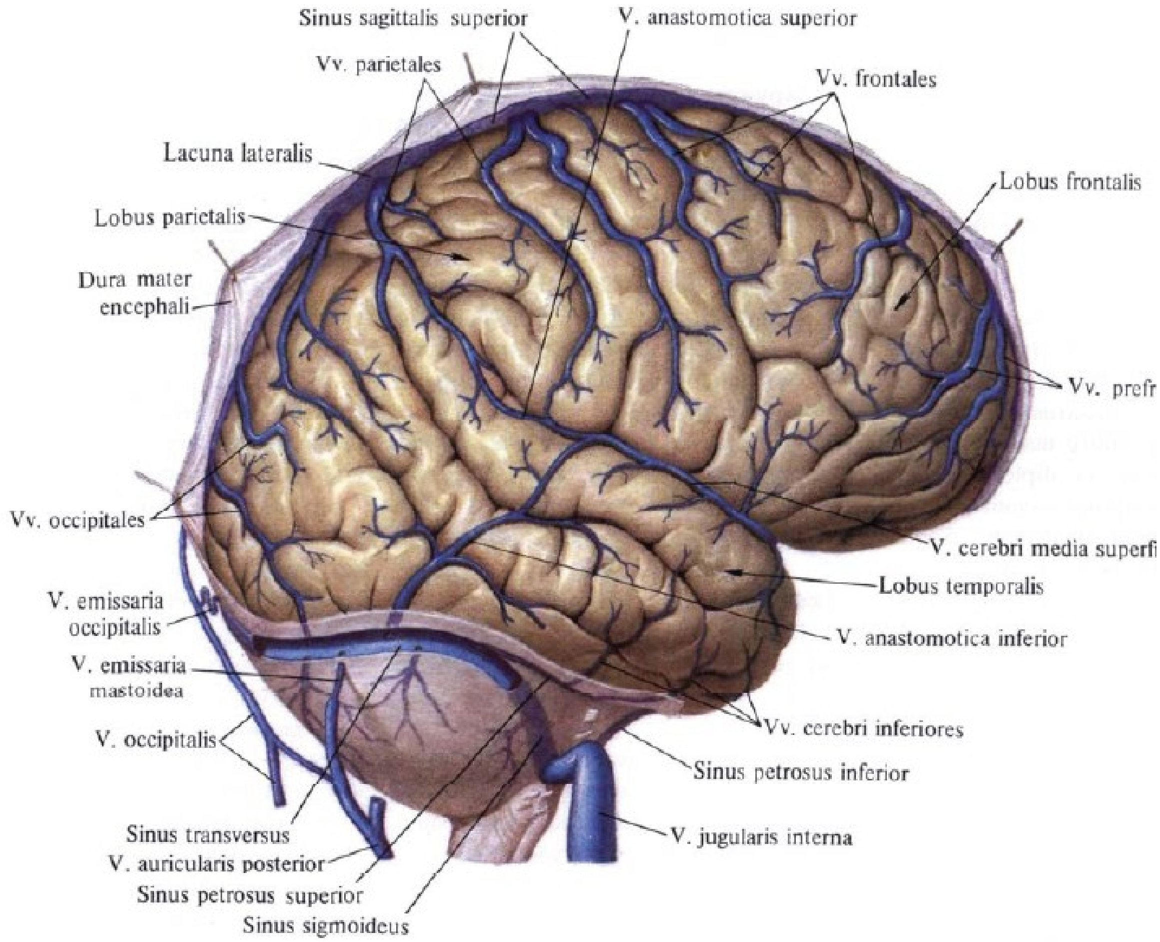
Sunus transversus
Dura mater encephali
Sinus occipitalis
Processus transversus atlantis
V. cervicalis profunda
Дуги позвонков в разрезе
Plexus venosus vertebralis internus posterior
Rr. dorsales vv. intercostales posteriores
Plexus venosus vertebralis internus anterior
Vv. intervertebrales
Mm. intercostales externi
Dura mater spinalis
V. lumbalis ascendens dextra
Vv. lumbales
lumbalis ascendens sinistra
V. glutea superior
V. glutea inferior

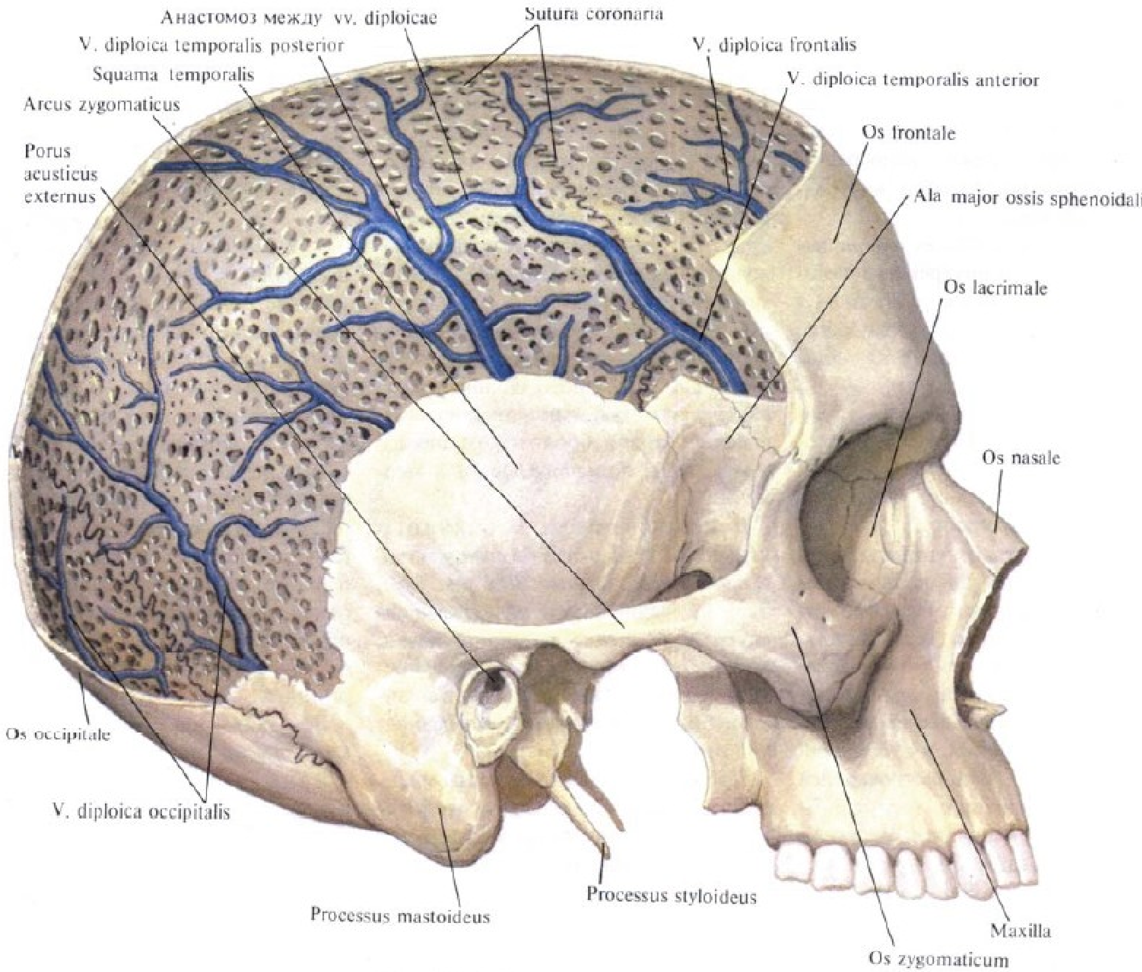


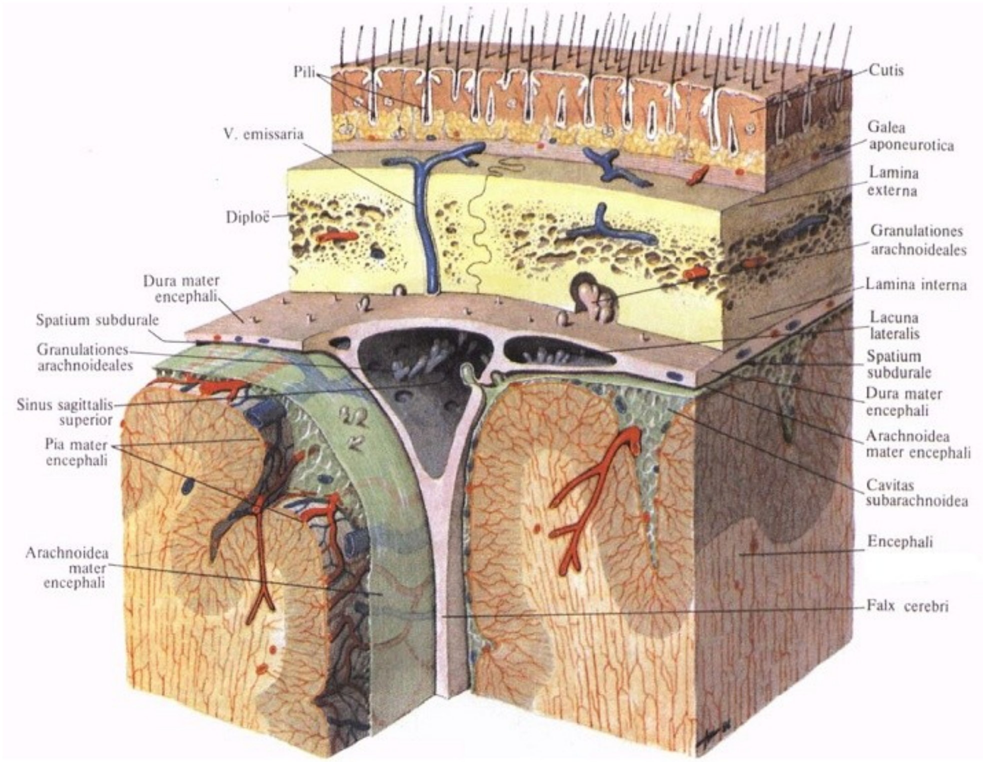
Vv. diploicae
V. emissaria parietalis
Sinus sagittalis superior
Falx cerebri
Sinus cavernosus
Sinus sagittalis inferior
V. supratrochlearis
V. temporalis superficialis
V. ophthalmica superior
V. cerebri magna
Sinus rectus
V. nasofrontalis
Sinus petrosus superior
V. nasalis externa
Confluens sinuum
V. ophthalmica inferior
Sinus petrosus inferior
Sinus occipitalis
V. angularis
Sinus transversus
Sinus sigmoideus
Plexus pterygoideus
Bulbus v. jugularis superior
V. facialis
V. labialis superior
V. emissaria occipitalis
V. auricularis posterior
V. transversa faciei
V. emissaria mastoidea
V. pharyngea
V. occipitalis
V. retromandibularis
V. labialis inferior
V. lingualis
Plexus venosi vertebrales externi
V. facialis
V. facialis
V. submentalis
Os hyoideum
V. jugularis externa
V. jugularis interna
V. thyroidea superior
V. cervicalis profunda
Cartilago thyroidea
V. jugularis anterior
V. vertebralis
V. transversa colli
V. thyroidea inferior
Bulbus v. jugularis inferior
V. suprascapularis
V. subclavia dextra
V. brachiocephalica sinistra
V. brachiocephalica dextra
Vv. thoracicae internae
V. cava superior

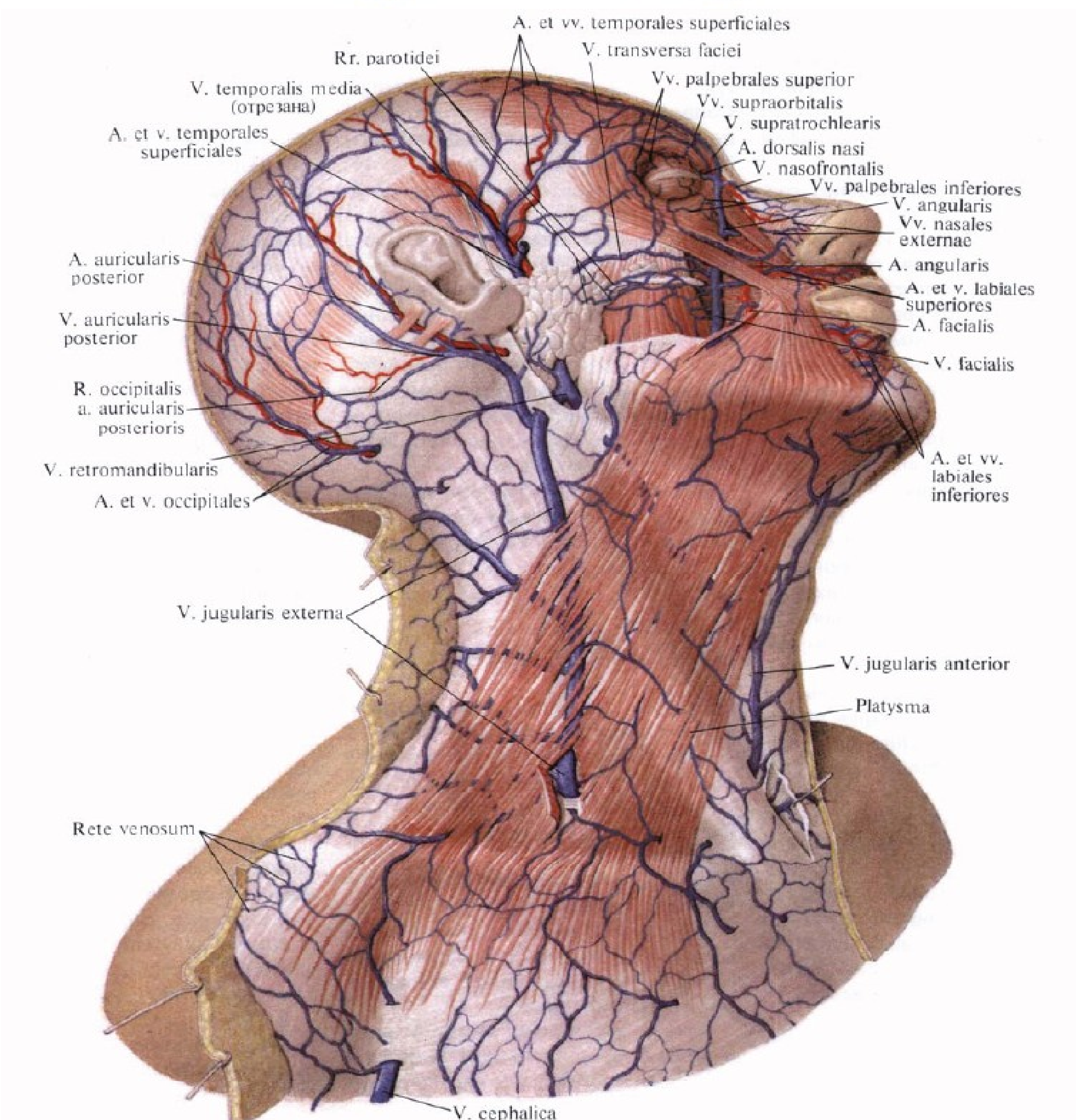


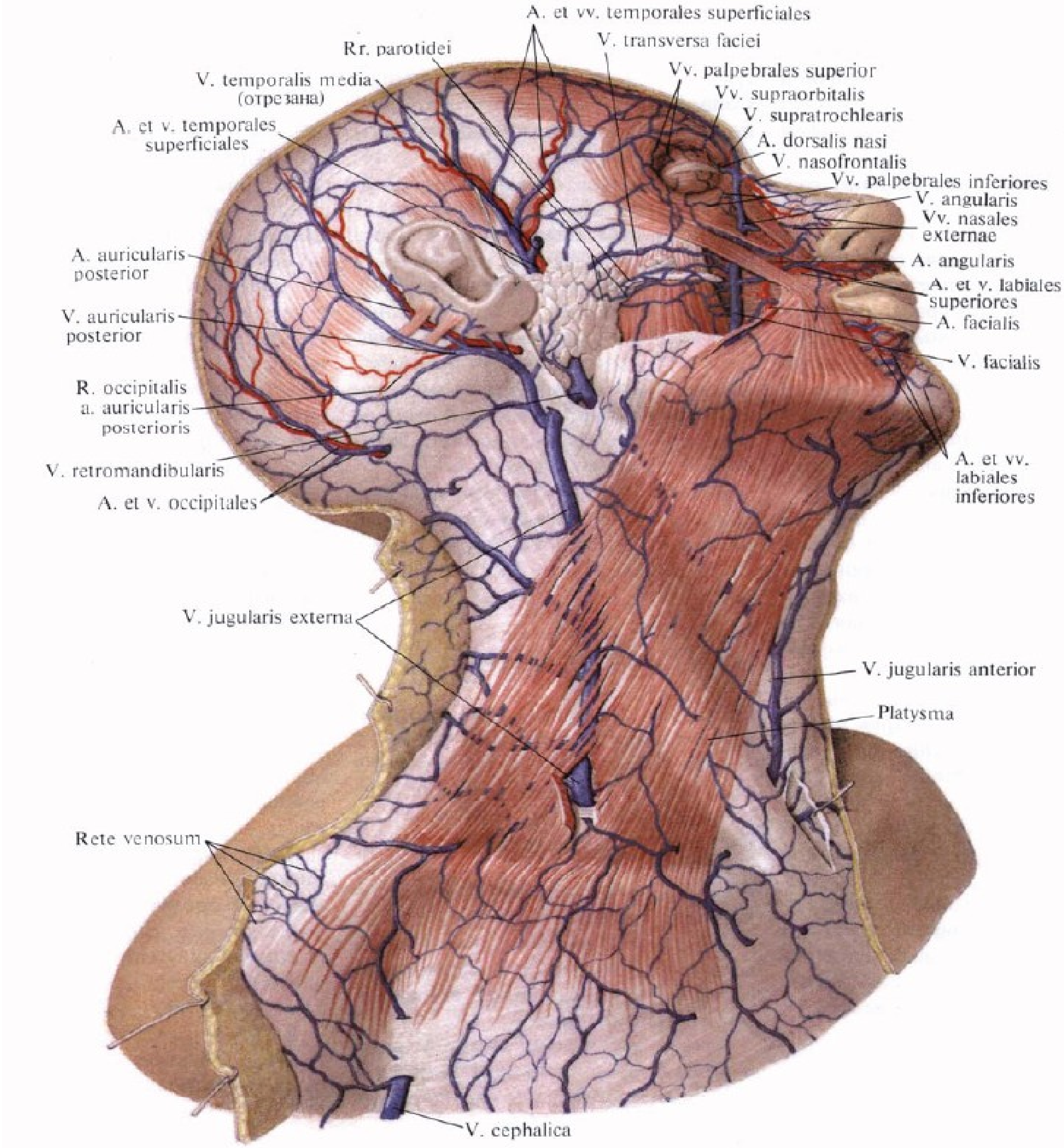
V. temporalis superficialis
V. emissaria parietalis
V. talamostriata superior
Sinus sagittalis inferior
Ventriculus lateralis
V. choroidea superior
Lamina septi pellucidi
Genu corporis callosi
Lacunae laterales
V. septi pellucidi anterior
Sinus sagittalis superior
Columna fornicis
Tela choroidea ventriculi tercii
Sinus intercavernosi
V. cerebri interna
Pons
Sinus sphenoparietalis
Falx cerebri major
Vv. cerebri superiores
N. opticus
A. carotis interna
V. cerebri media superficialis
Sinus rectus
Sinus cavernosus
Ventriculus quartus
Plexus venosus foraminis ovalis
Sinus petrosus superior
Sinus petrosus inferior
Confluens sinuum
Sinus sigmoideus
Vv. diploicae
Plexus venosus canalis hypoglossi
Sinus occipitalis
Plexus basilaris
Sinus transversus
Medulla oblongata
V. magna cerebri
V. basalis

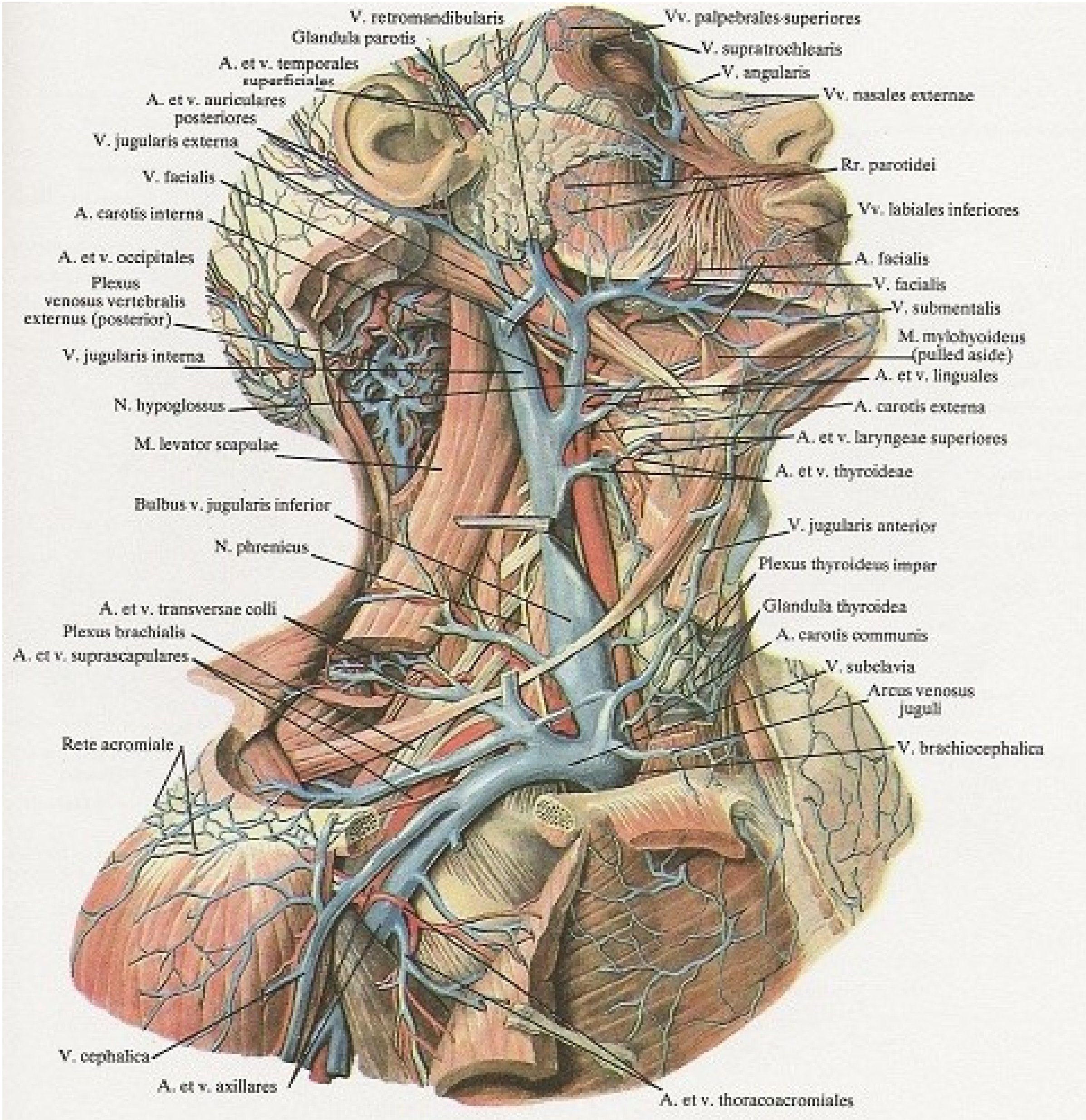

Sinus sagittalis superior
V. anastomotica superior
Vv. parietales
Vv. frontales
Lacuna lateralis
Lobus frontalis
Lobus parietalis
Dura mater encephali
Vv. prefr
Vv. occipitales
V. cerebri media superfi
Lobus temporalis
V. emissaria occipitalis
V. anastomotica inferior
V. emissaria mastoidea
Vv. cerebri inferiores
V. occipitalis
Sinus petrosus inferior
Sinus transversus
V. jugularis interna
V. auricularis posterior
Sinus petrosus superior
Sinus sigmoideus


Анастомоз между vv. diploicae
Sutura coronaria
V. diploica temporalis posterior
V. diploica frontalis
Squama temporalis
V. diploica temporalis anterior
Arcus zygomaticus
Os frontale
Porus
acusticus
externus
Ala major ossis sphenoidalis
Os lacrimale
Os nasale
Os occipitale
V. diploica occipitalis
Processus mastoideus
Processus styloideus
Maxilla
Os zygomaticum

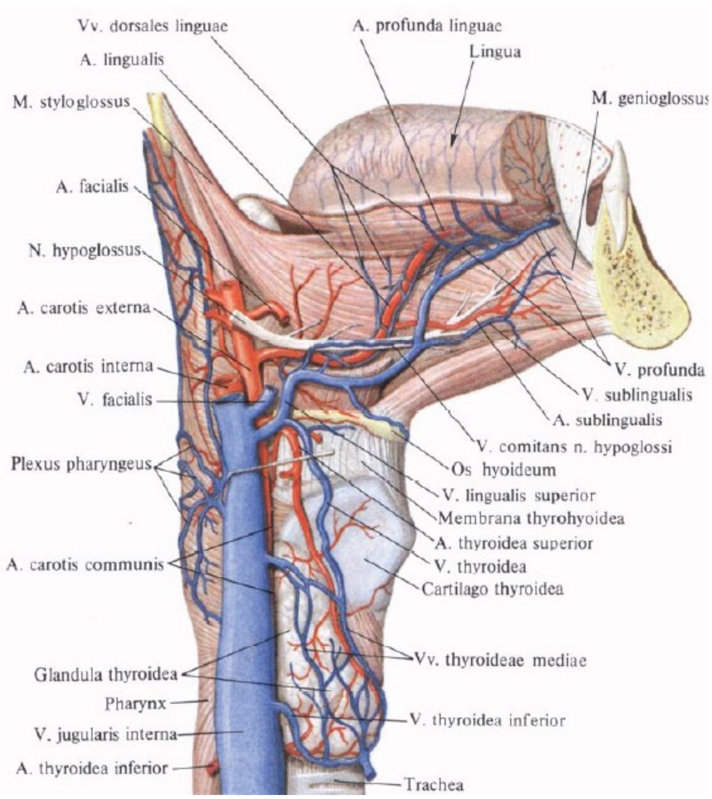

Pili
Cutis
V. emissaria
Galea aponeurotica
Lamina externa
Diploë
Granulationes arachnoideales
Dura mater encephali
Lamina interna
Spatium subdurale
Lacuna lateralis
Granulationes arachnoideales
Spatium subdurale
Dura mater encephali
Sinus sagittalis superior
Arachnoidea mater encephali
Pia mater encephali
Cavitas subarachnoidea
Encephali
Arachnoidea mater encephali
Falx cerebri

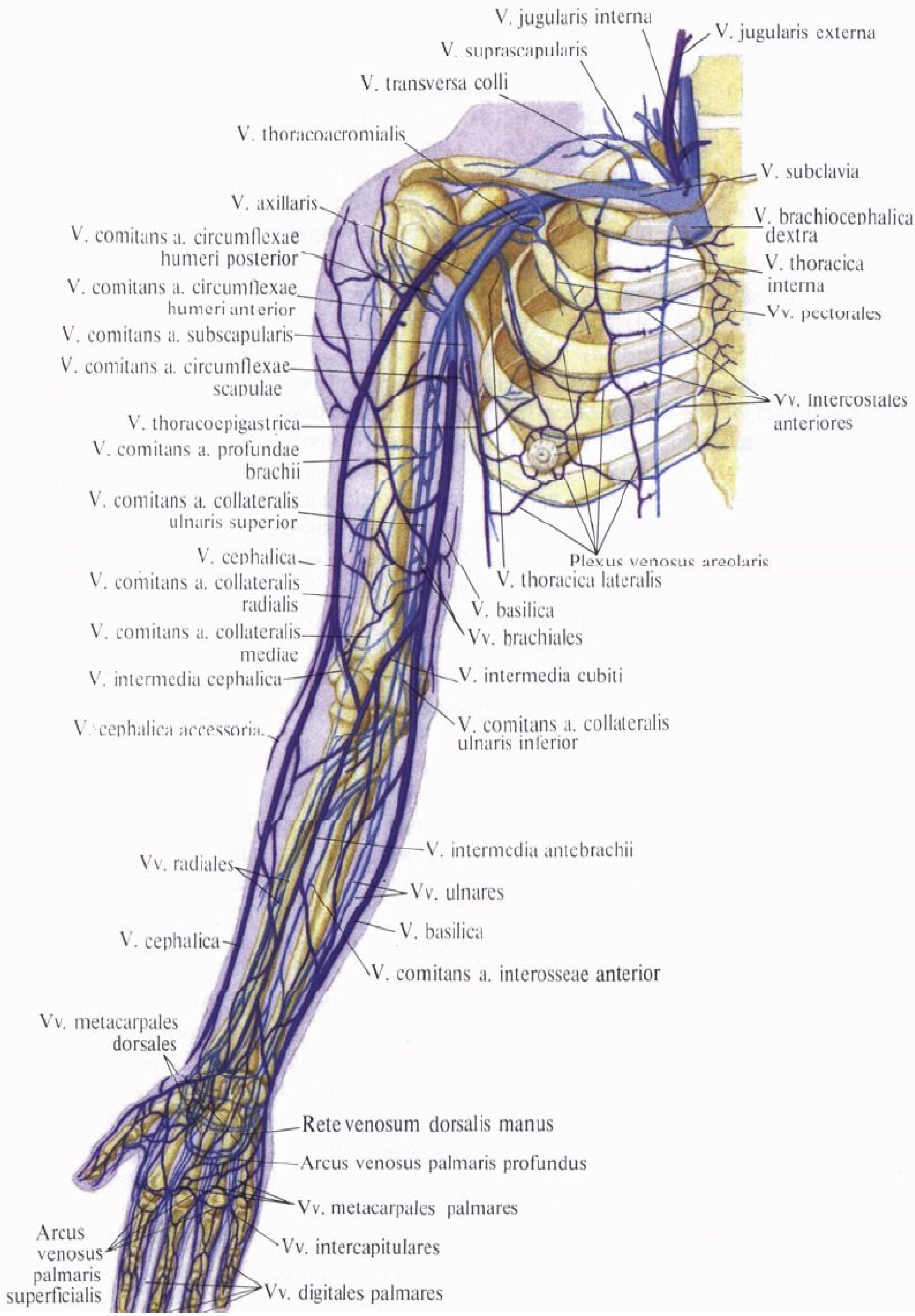

A. et vv. temporales superficiales
Rr. parotidei
V. transversa faciei
V. temporalis media (отрезана)
Vv. palpebrales superior
Vv. supraorbitalis
A. et v. temporales superficiales
V. supratrochlearis
A. dorsalis nasi
V. nasofrontalis
Vv. palpebrales inferiores
V. angularis
Vv. nasales externae
A. auricularis posterior
A. angularis
A. et v. labiales superiores
V. auricularis posterior
A. facialis
V. facialis
R. occipitalis a. auricularis posterioris
V. retromandibularis
A. et vv. labiales inferiores
A. et v. occipitales
V. jugularis externa
V. jugularis anterior
Platysma
Rete venosum
V. cephalica

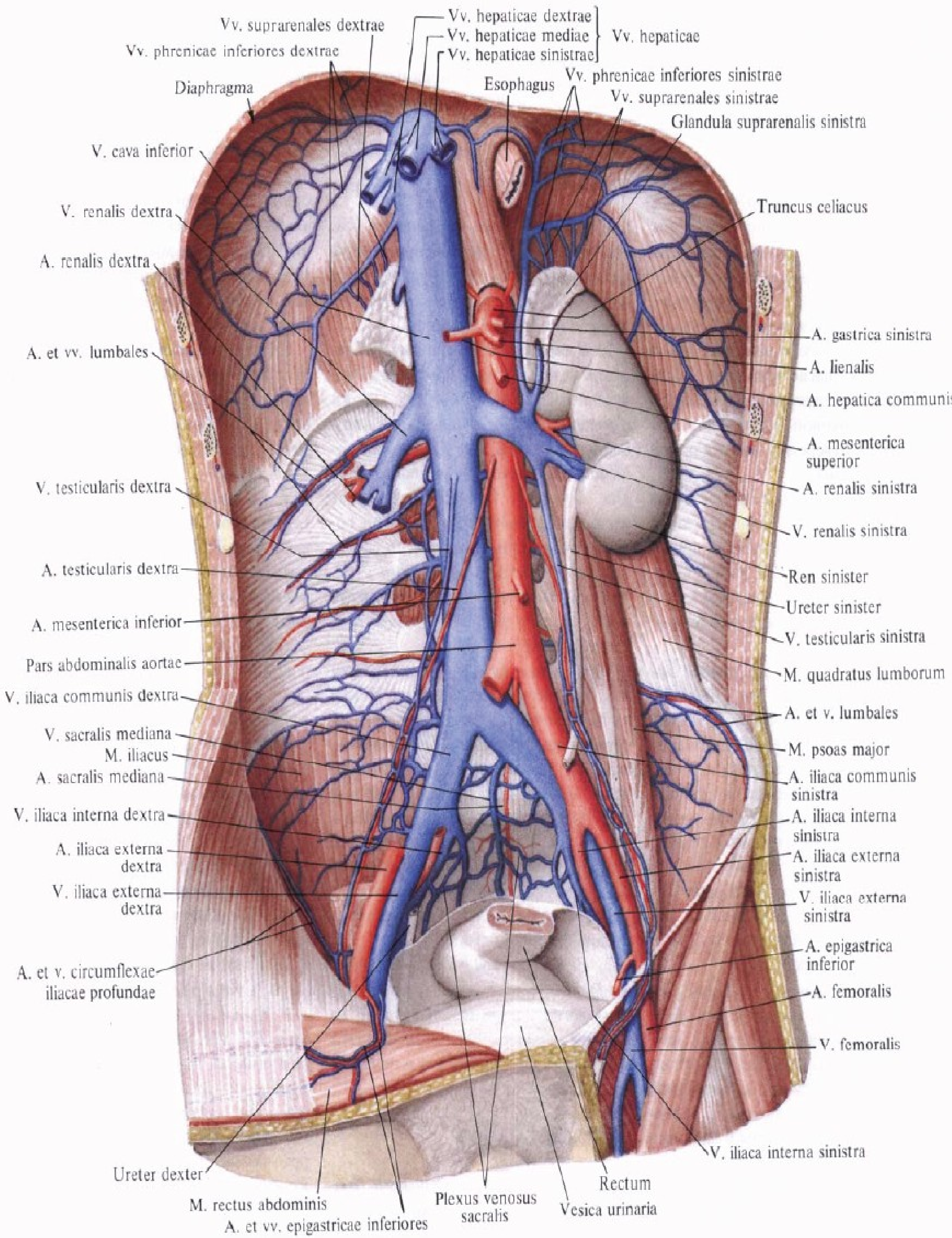

A. et vv. temporales superficiales
Rr. parotidei
V. transversa faciei
V. temporalis media
(отрезана)
Vv. palpebrales superior
Vv. supraorbitalis
V. supratrochlearis
A. et v. temporales
superficiales
A. dorsalis nasi
V. nasofrontalis
Vv. palpebrales inferiores
V. angularis
Vv. nasales
externae
A. auricularis
posterior
A. angularis
A. et v. labiales
superiores
V. auricularis
posterior
A. facialis
V. facialis
R. occipitalis
a. auricularis
posterioris
V. retromandibularis
A. et vv.
labiales
inferiores
A. et v. occipitales
V. jugularis externa
V. jugularis anterior
Platysma
Rete venosum
V. cephalica

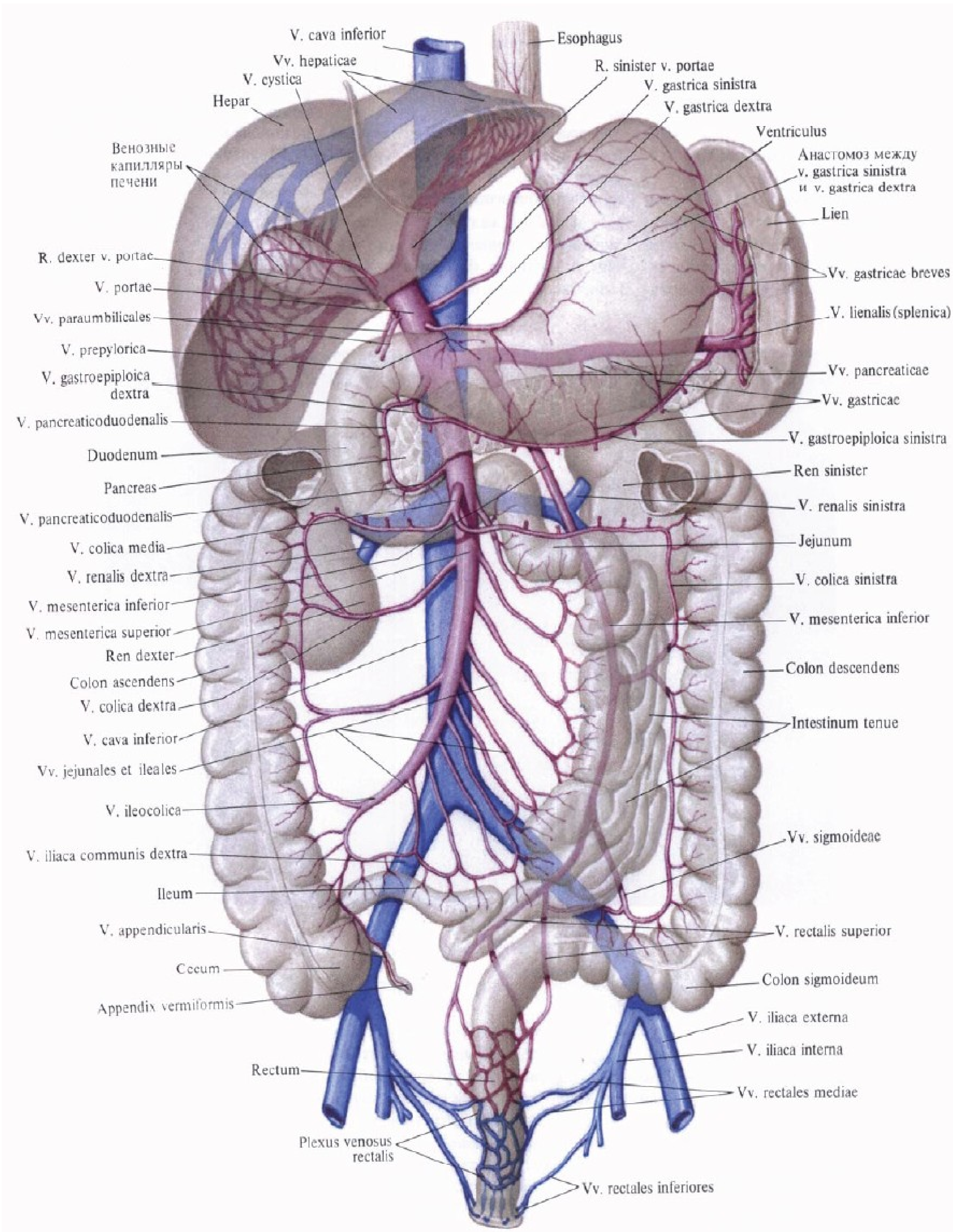


V. retromandibularis
Glandula parotis
A. et v. temporales superficiales
A. et v. auriculares posteriores
V. jugularis externa
V. facialis
A. carotis interna
A. et v. occipitales
Plexus venosus vertebralis externus (posterior)
V. jugularis interna
N. hypoglossus
M. levator scapulae
Bulbus v. jugularis inferior
N. phrenicus
A. et v. transversae colli
Plexus brachialis
A. et v. suprascapulares
Rete acromiale
V. cephalica
A. et v. axillares
Vv. palpebrales superiores
V. supratrochlearis
V. angularis
Vv. nasales externae
Rr. parotidei
Vv. labiales inferiores
A. facialis
V. facialis
V. submentalis
M. mylohyoideus (pulled aside)
A. et v. linguales
A. carotis externa
A. et v. laryngeae superiores
A. et v. thyroideae
V. jugularis anterior
Plexus thyroideus impar
Glandula thyroidea
A. carotis communis
V. subclavia
Arcus venosus juguli
V. brachiocephalica
A. et v. thoracoacromiales

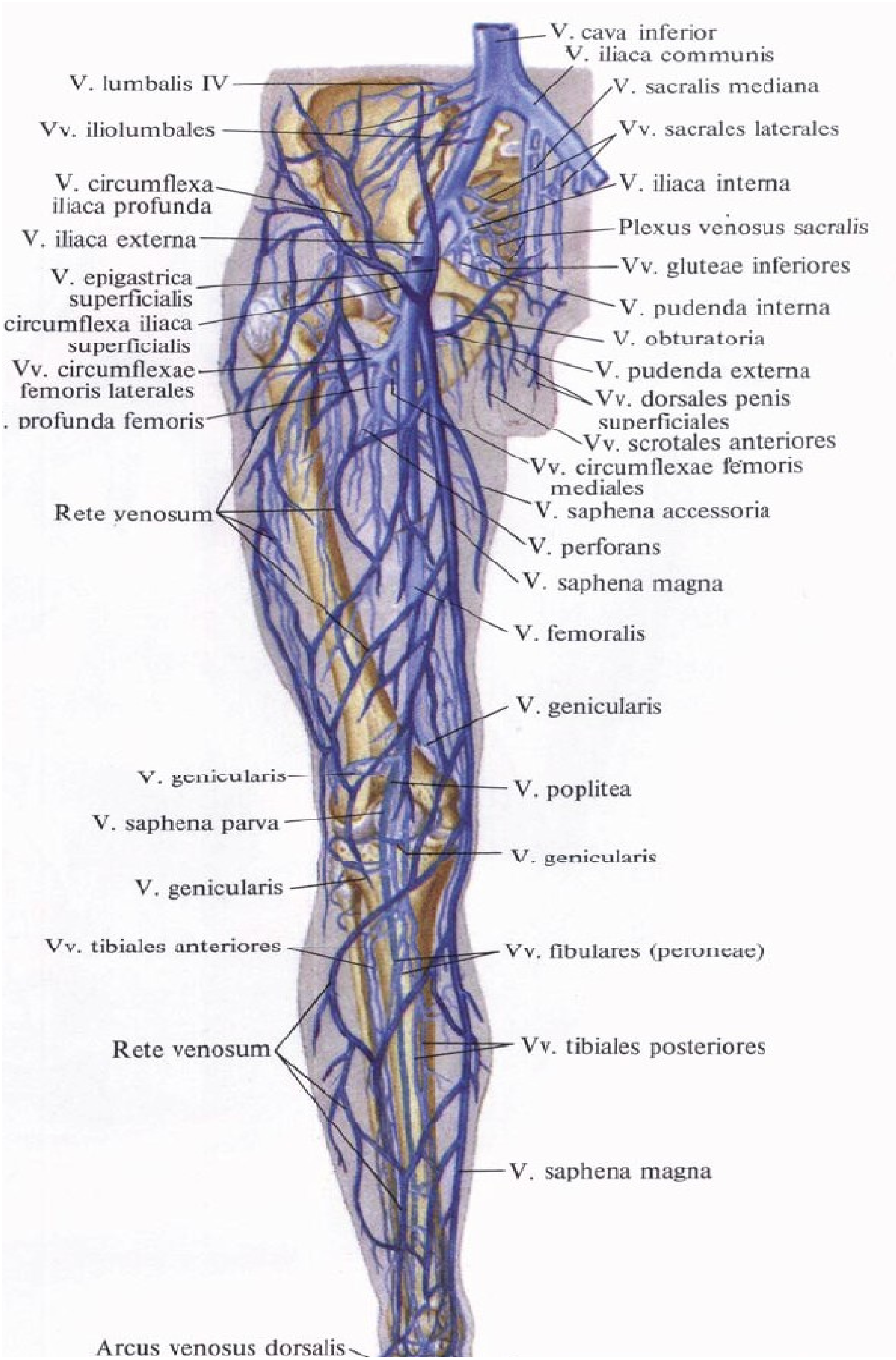

Vv. dorsales linguae
A. profunda linguae
Lingua
A. lingualis
M. styloglossus
M. genioglossus
A. facialis
N. hypoglossus
A. carotis externa
A. carotis interna
V. facialis
V. profunda
V. sublingualis
A. sublingualis
V. comitans n. hypoglossi
Plexus pharyngeus
Os hyoideum
V. lingualis superior
Membrana thyrohyoidea
A. thyroidea superior
V. thyroidea
A. carotis communis
Cartilago thyroidea
Vv. thyroideae mediae
Glandula thyroidea
Pharynx
V. thyroidea inferior
V. jugularis interna
A. thyroidea inferior
Trachea


V. jugularis interna
V. jugularis externa
V. suprascapularis
V. transversa colli
V. thoracoacromialis
V. subclavia
V. axillaris
V. brachiocephalica dextra
V. comitans a. circumflexae humeri posterior
V. thoracica interna
V. comitans a. circumflexae humeri anterior
Vv. pectorales
V. comitans a. subscapularis
V. comitans a. circumflexae scapulae
Vv. intercostales anteriores
V. thoracoepigastrica
V. comitans a. profundae brachii
V. comitans a. collateralis ulnaris superior
V. cephalica
Plexus venosus areolaris
V. comitans a. collateralis radialis
V. thoracica lateralis
V. basilica
V. comitans a. collateralis mediae
Vv. brachiales
V. intermedia cephalica
V. intermedia cubiti
V. cephalica accessoria
V. comitans a. collateralis ulnaris inferior
V. intermedia antebrachii
Vv. radiales
Vv. ulnares
V. basilica
V. cephalica
V. comitans a. interosseae anterior
Vv. metacarpales dorsales
Rete venosum dorsalis manus
Arcus venosus palmaris profundus
Vv. metacarpales palmares
Arcus venosus palmaris superficialis
Vv. intercapitulares
Vv. digitales palmares

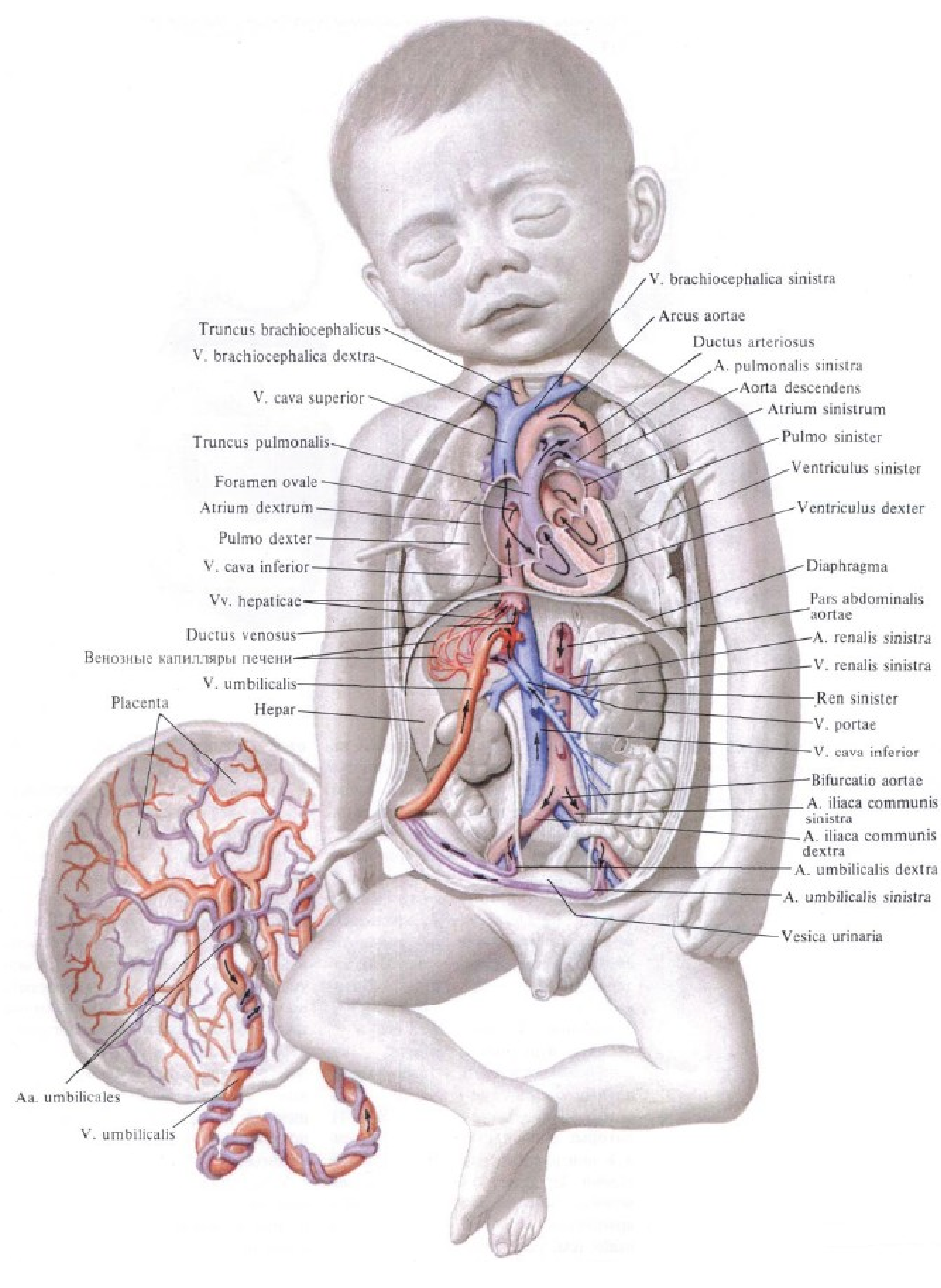

Vv. suprarenales dextrae
Vv. hepaticae dextrae
Vv. hepaticae mediae
Vv. hepaticae sinistrae
Vv. hepaticae
Vv. phrenicae inferiores dextrae
Diaphragma
Esophagus
Vv. phrenicae inferiores sinistrae
Vv. suprarenales sinistrae
Glandula suprarenalis sinistra
V. cava inferior
V. renalis dextra
Truncus celiacus
A. renalis dextra
A. gastrica sinistra
A. et vv. lumbales
A. lienalis
A. hepatica communis
A. mesenterica superior
A. renalis sinistra
V. testicularis dextra
V. renalis sinistra
A. testicularis dextra
Ren sinister
Ureter sinister
A. mesenterica inferior
V. testicularis sinistra
Pars abdominalis aortae
M. quadratus lumborum
V. iliaca communis dextra
A. et v. lumbales
V. sacralis mediana
M. psoas major
M. iliacus
A. sacralis mediana
A. iliaca communis sinistra
V. iliaca interna dextra
A. iliaca interna sinistra
A. iliaca externa dextra
A. iliaca externa sinistra
V. iliaca externa dextra
V. iliaca externa sinistra
A. epigastrica inferior
A. et v. circumflexae iliacae profundae
A. femoralis
V. femoralis
V. iliaca interna sinistra
Ureter dexter
Rectum
M. rectus abdominis
Plexus venosus sacralis
Vesica urinaria
A. et vv. epigastricae inferiores



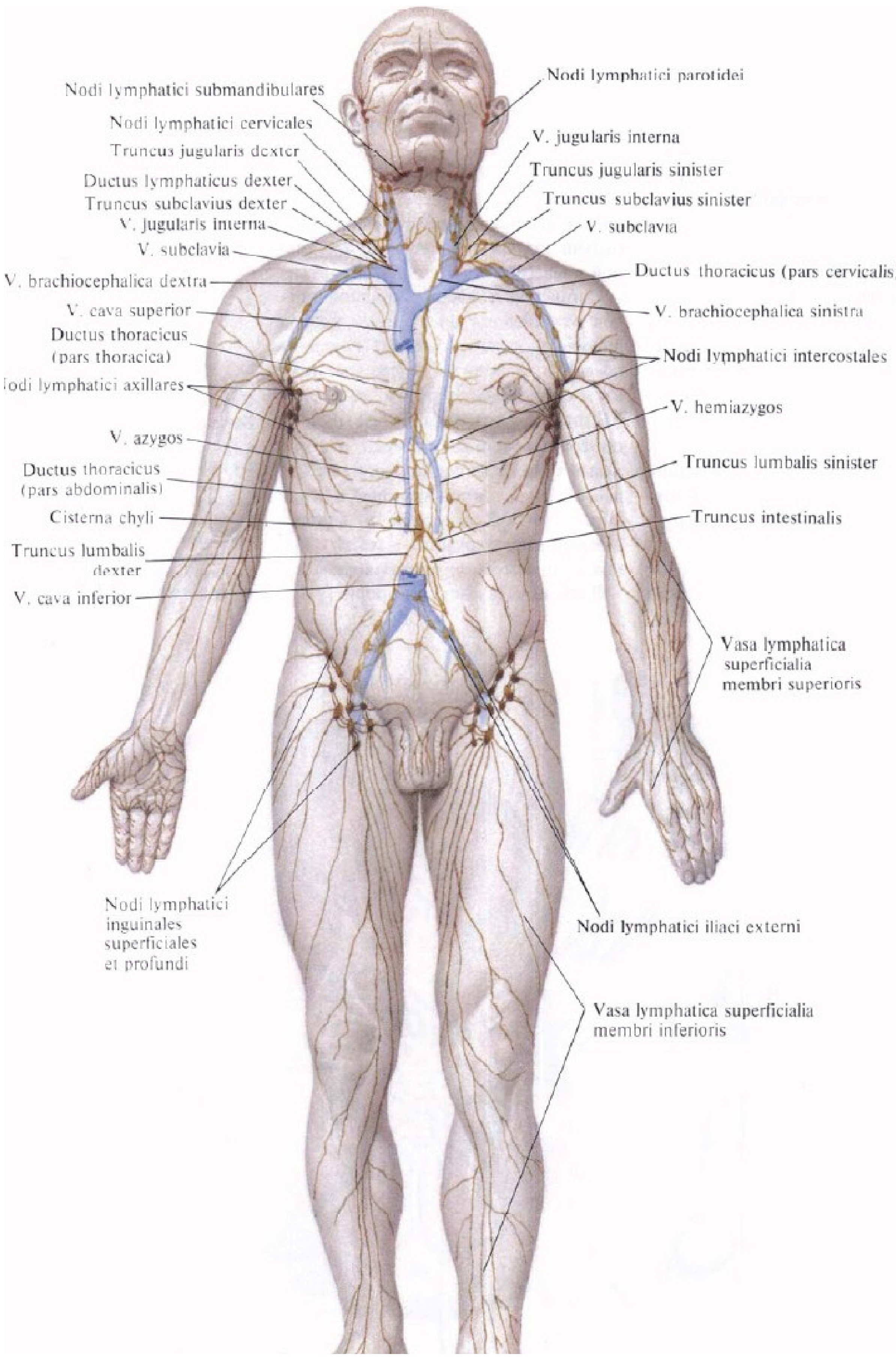
V. cava inferior
Esophagus
Vv. hepaticae
R. sinister v. portae
V. cystica
V. gastrica sinistra
Hepar
V. gastrica dextra
Ventriculus
Венозные
капилляры
печени
Анастомоз между
v. gastrica sinistra
и v. gastrica dextra
Lien
R. dexter v. portae
Vv. gastricae breves
V. portae
V. lienalis (splenica)
Vv. paraumbilicales
V. prepylorica
Vv. pancreaticae
V. gastroepiploica
dextra
Vv. gastricae
V. pancreaticoduodenalis
V. gastroepiploica sinistra
Duodenum
Ren sinister
Pancreas
V. pancreaticoduodenalis
V. renalis sinistra
V. colica media
Jejunum
V. renalis dextra
V. colica sinistra
V. mesenterica inferior
V. mesenterica superior
V. mesenterica inferior
Ren dexter
Colon descendens
Colon ascendens
V. colica dextra
Intestinum tenue
V. cava inferior
Vv. jejunales et ileales
V. ileocolica
Vv. sigmoideae
V. iliaca communis dextra
Ileum
V. appendicularis
V. rectalis superior
Cecum
Colon sigmoideum
Appendix vermiformis
V. iliaca externa
V. iliaca interna
Rectum
Vv. rectales mediae
Plexus venosus
rectalis
Vv. rectales inferiores

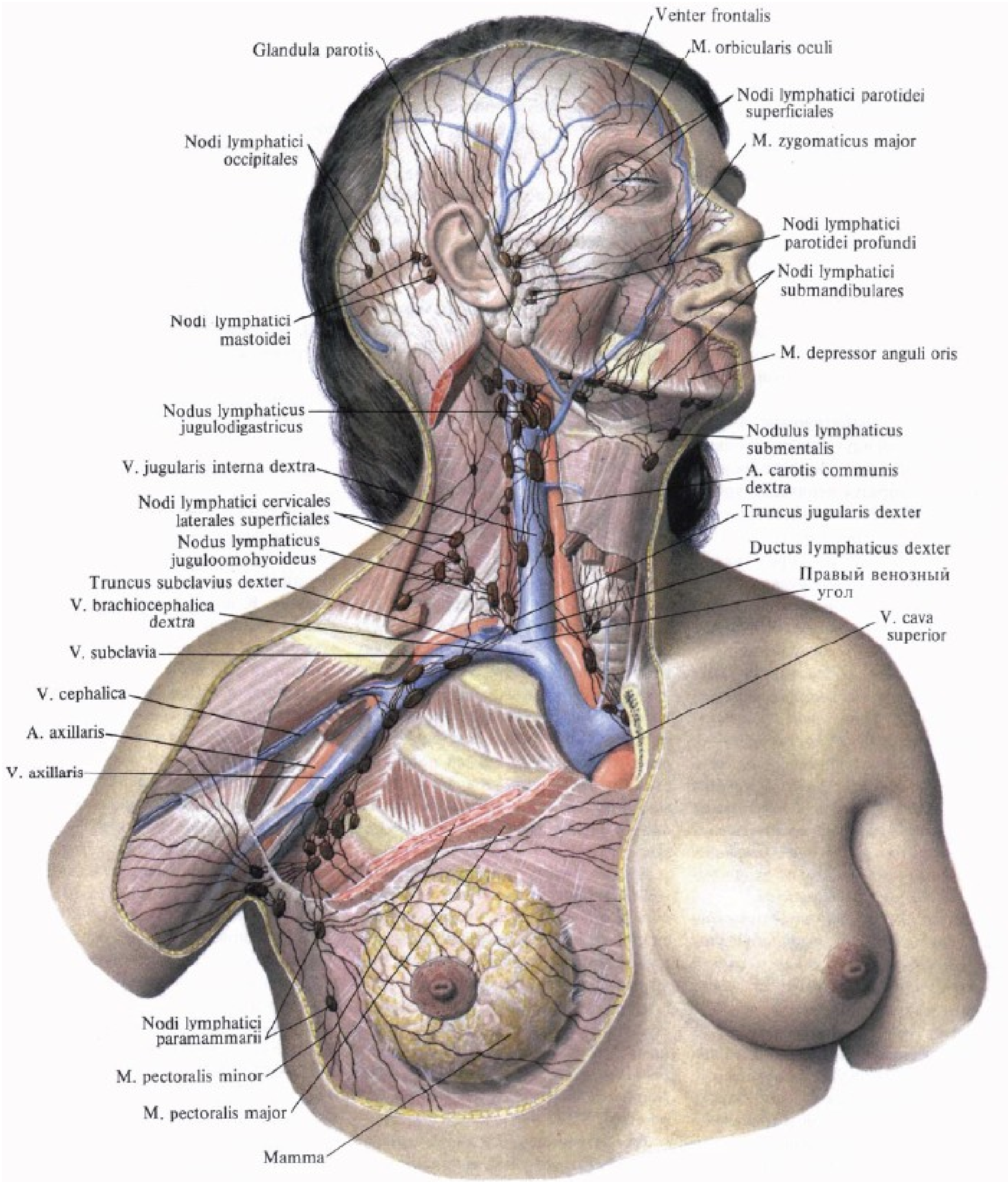


V. cava inferior
V. iliaca communis
V. lumbalis IV
V. sacralis mediana
Vv. iliolumbales
Vv. sacrales laterales
V. circumflexa iliaca profunda
V. iliaca interna
Plexus venosus sacralis
V. iliaca externa
Vv. gluteae inferiores
V. epigastrica superficialis
V. pudenda interna
circumflexa iliaca superficialis
V. obturatoria
Vv. circumflexae femoris laterales
V. pudenda externa
Vv. dorsales penis superficiales
. profunda femoris
Vv. scrotales anteriores
Vv. circumflexae femoris mediales
V. saphena accessoria
Rete venosum
V. perforans
V. saphena magna
V. femoralis
V. genicularis
V. genicularis
V. poplitea
V. saphena parva
V. genicularis
V. genicularis
Vv. tibiales anteriores
Vv. fibulares (peroneae)
Rete venosum
Vv. tibiales posteriores
V. saphena magna
Arcus venosus dorsalis

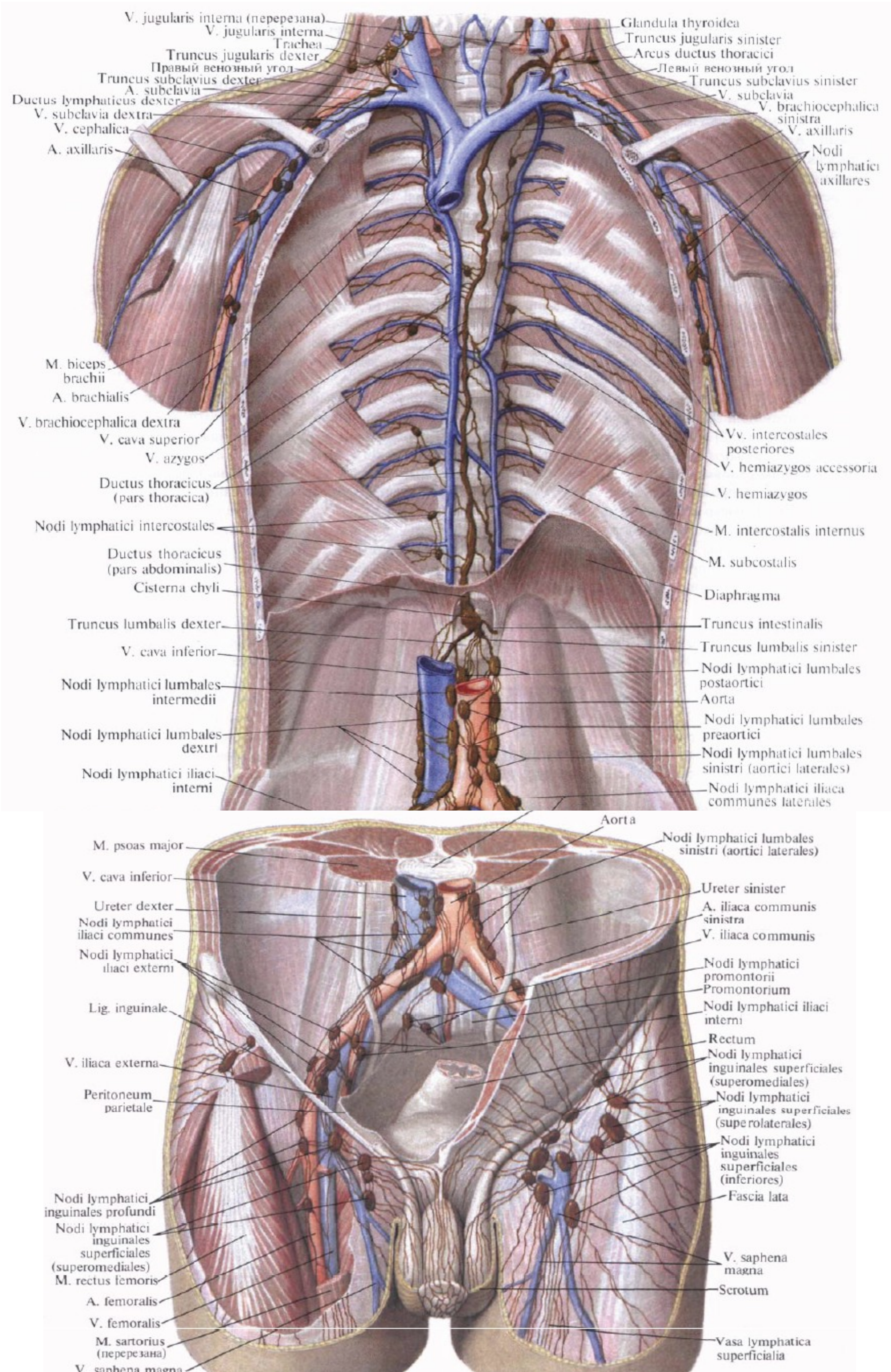


V. brachiocephalica sinistra
Arcus aortae
Ductus arteriosus
A. pulmonalis sinistra
Aorta descendens
Atrium sinistrum
Pulmo sinister
Ventriculus sinister
Ventriculus dexter
Diaphragma
Pars abdominalis aortae
A. renalis sinistra
V. renalis sinistra
Ren sinister
V. portae
V. cava inferior
Bifurcatio aortae
A. iliaca communis sinistra
A. iliaca communis dextra
A. umbilicalis dextra
A. umbilicalis sinistra
Vesica urinaria
Truncus brachiocephalicus
V. brachiocephalica dextra
V. cava superior
Truncus pulmonalis
Foramen ovale
Atrium dextrum
Pulmo dexter
V. cava inferior
Vv. hepaticae
Ductus venosus
Венозные капилляры печени
V. umbilicalis
Placenta
Hepar
Aa. umbilicales
V. umbilicalis

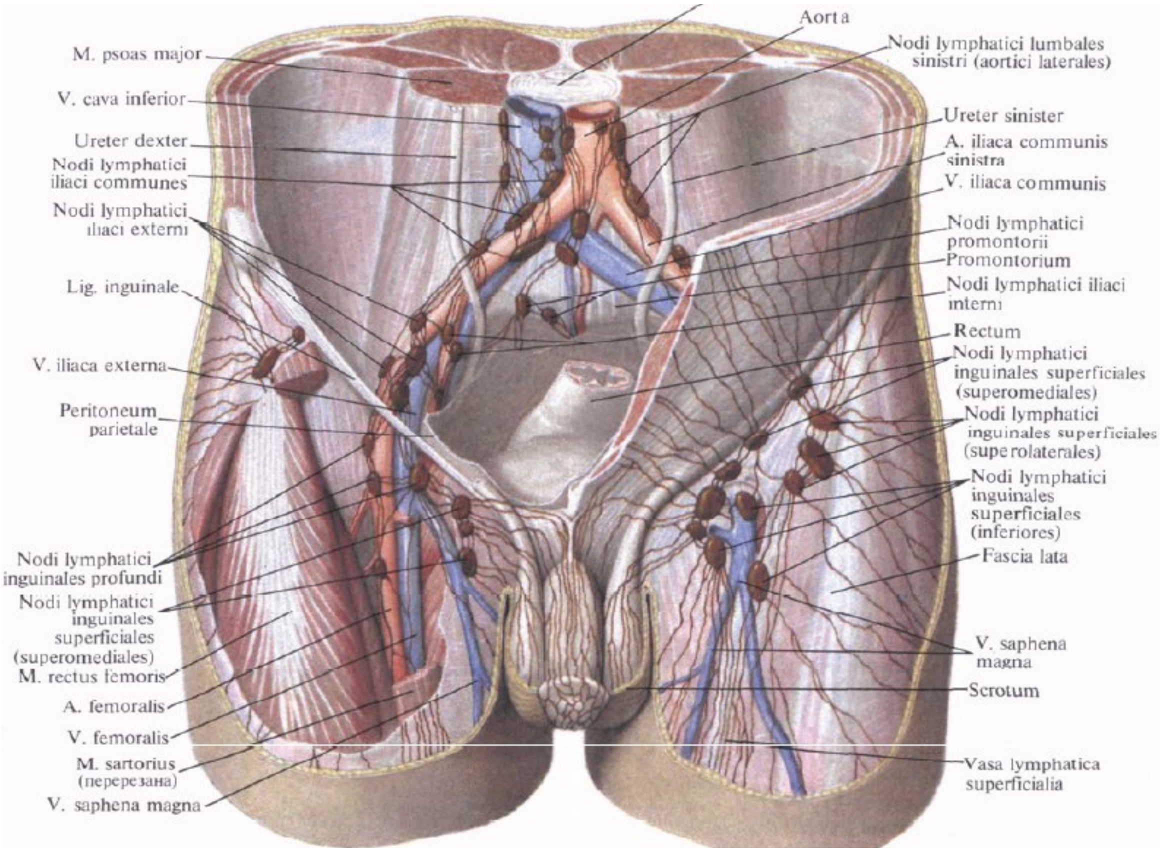

Nodi lymphatici submandibulares
Nodi lymphatici cervicales
Truncus jugularis dexter
Ductus lymphaticus dexter
Truncus subclavius dexter
V. jugularis interna
V. subclavia
V. brachiocephalica dextra
V. cava superior
Ductus thoracicus
(pars thoracica)
lodi lymphatici axillares
V. azygos
Ductus thoracicus
(pars abdominalis)
Cisterna chyli
Truncus lumbalis
dexter
V. cava inferior
Nodi lymphatici
inguinales
superficiales
et profundi
Nodi lymphatici parotidei
V. jugularis interna
Truncus jugularis sinister
Truncus subclavius sinister
V. subclavia
Ductus thoracicus (pars cervicalis)
V. brachiocephalica sinistra
Nodi lymphatici intercostales
V. hemiazygos
Truncus lumbalis sinister
Truncus intestinalis
Vasa lymphatica
superficialia
membri superioris
Nodi lymphatici iliaci externi
Vasa lymphatica superficialia
membri inferioris



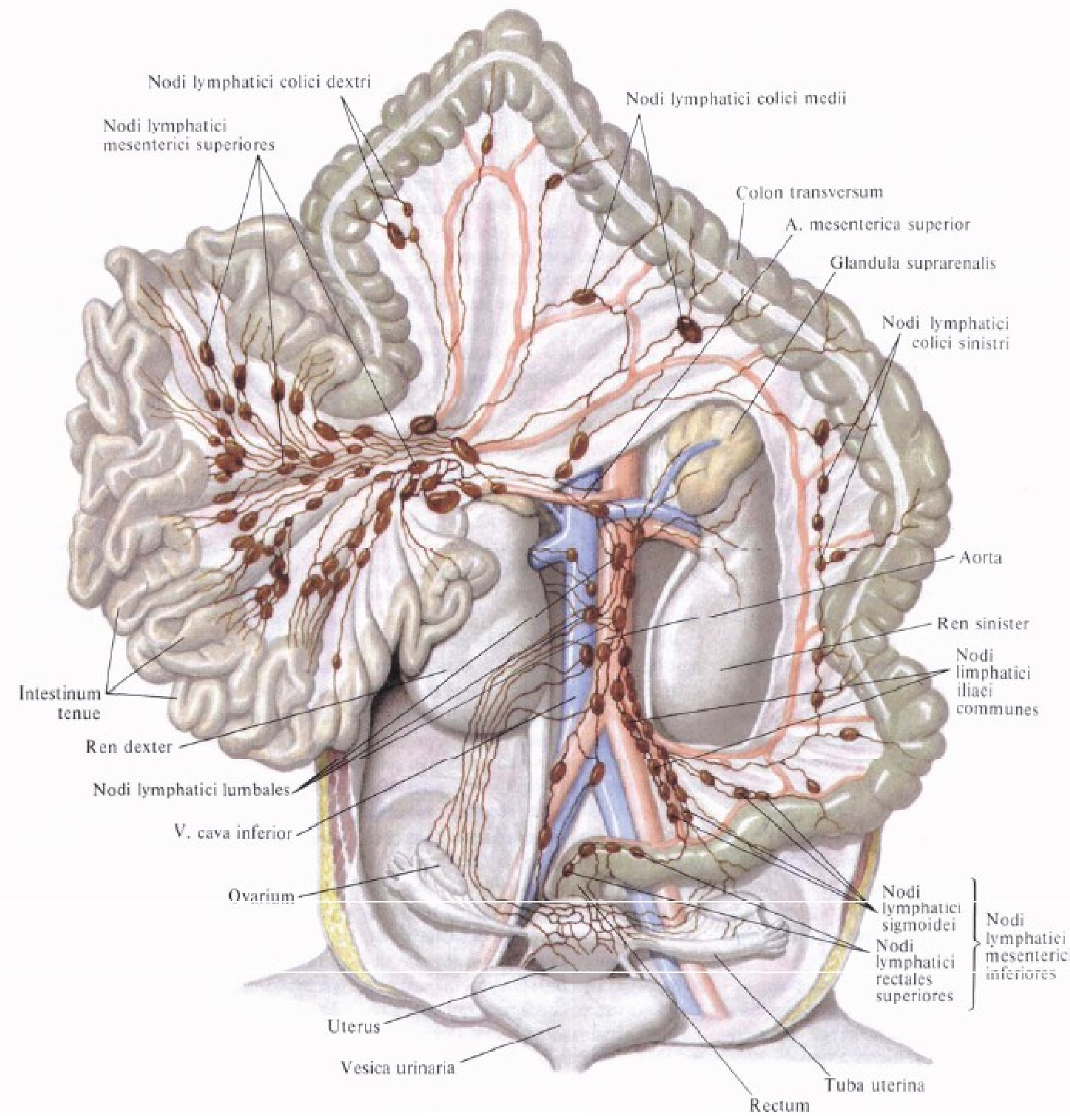
Venter frontalis
Glandula parotis
M. orbicularis oculi
Nodi lymphatici parotidei superficiales
Nodi lymphatici occipitales
M. zygomaticus major
Nodi lymphatici parotidei profundi
Nodi lymphatici submandibulares
Nodi lymphatici mastoidei
M. depressor anguli oris
Nodus lymphaticus jugulodigastricus
Nodulus lymphaticus submentalis
V. jugularis interna dextra
A. carotis communis dextra
Nodi lymphatici cervicales laterales superficiales
Truncus jugularis dexter
Nodus lymphaticus juguloomohyoideus
Ductus lymphaticus dexter
Truncus subclavius dexter
Правый венозный угол
V. brachiocephalica dextra
V. cava superior
V. subclavia
V. cephalica
A. axillaris
V. axillaris
Nodi lymphatici paramammarii
M. pectoralis minor
M. pectoralis major
Mamma

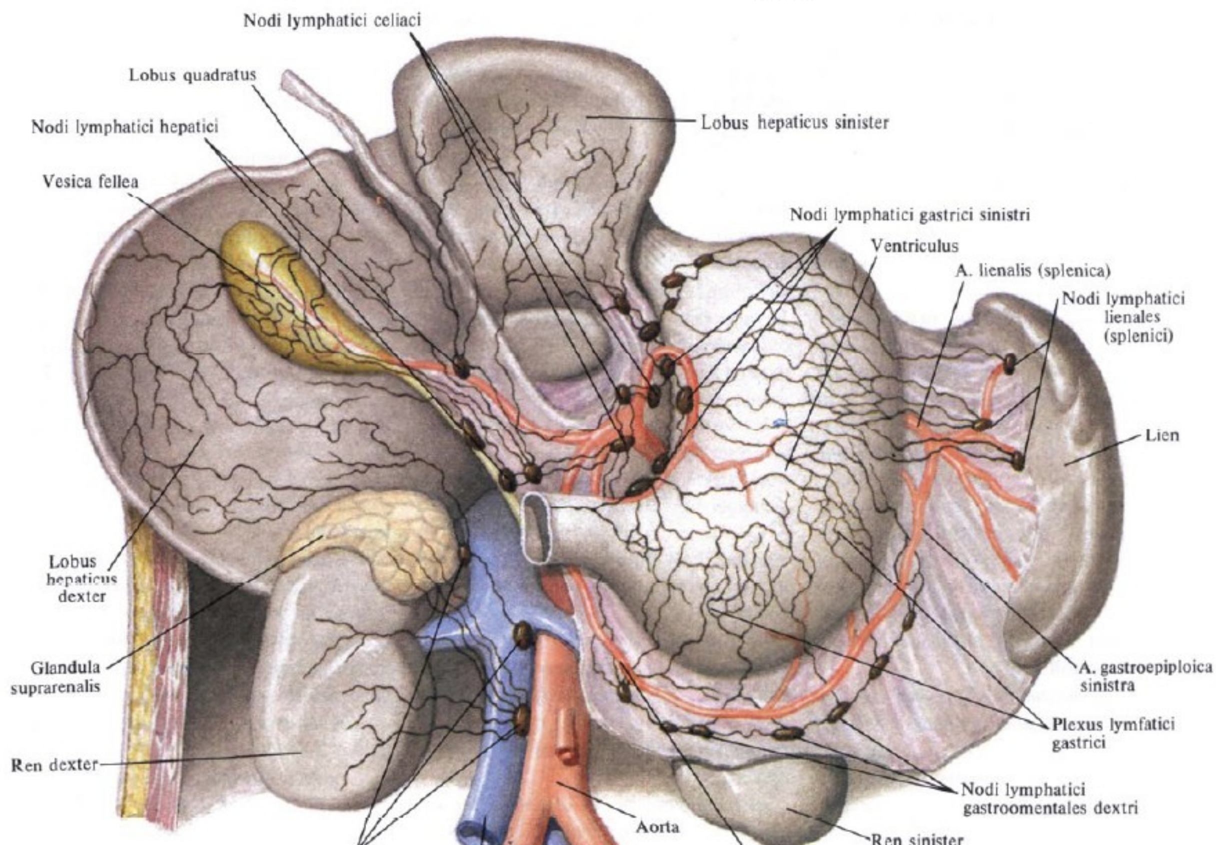


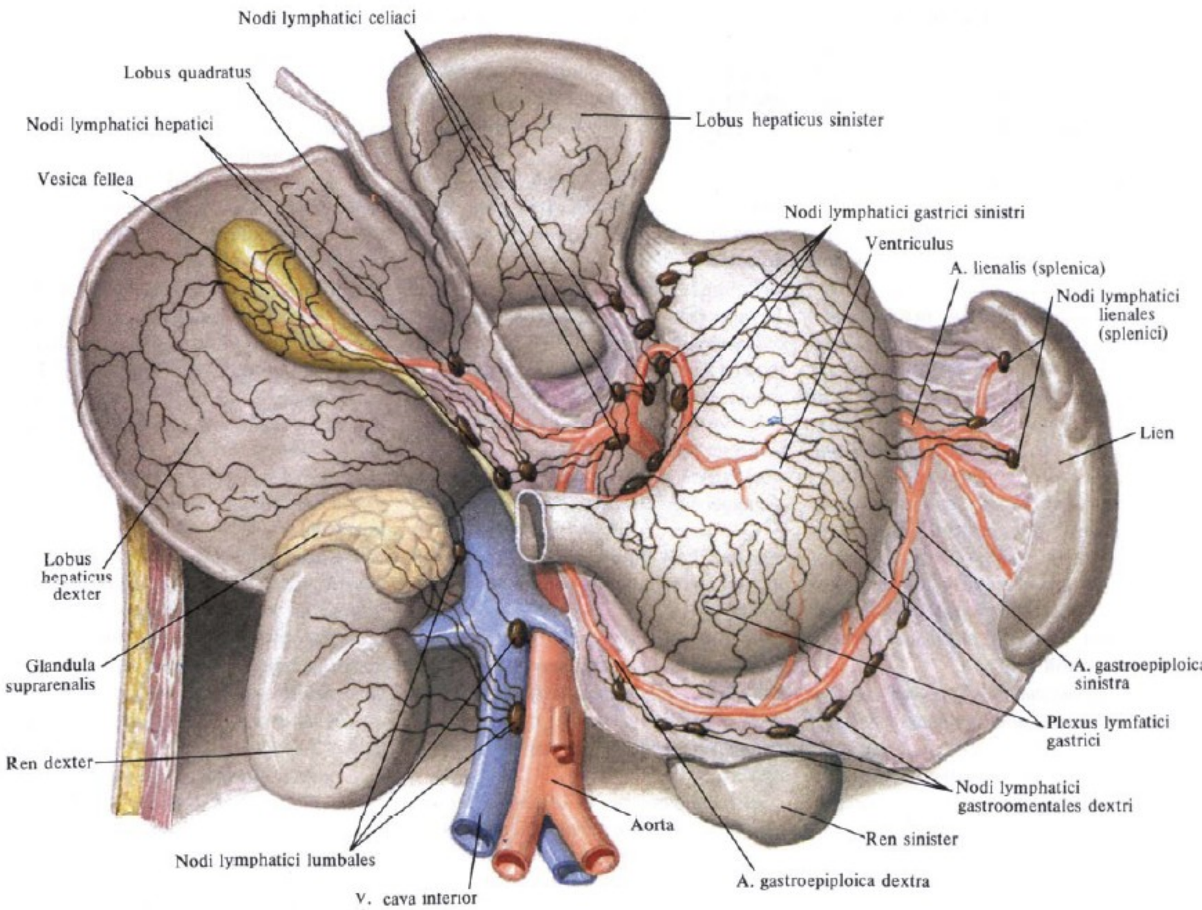
V. jugularis interna (перерезана)
V. jugularis interna
Trachea
Truncus jugularis dexter
Правый венозный угол
Truncus subclavius dexter
A. subclavia
Ductus lymphaticus dexter
V. subclavia dextra
V. cephalica
A. axillaris
M. biceps brachii
A. brachialis
V. brachiocephalica dextra
V. cava superior
V. azygos
Ductus thoracicus (pars thoracica)
Nodi lymphatici intercostales
Ductus thoracicus (pars abdominalis)
Cisterna chyli
Truncus lumbalis dexter
V. cava inferior
Nodi lymphatici lumbales intermedii
Nodi lymphatici lumbales dextri
Nodi lymphatici iliaci interni
Glandula thyroidea
Truncus jugularis sinister
Arcus ductus thoracici
Левый венозный угол
Truncus subclavius sinister
V. subclavia
V. brachiocephalica sinistra
V. axillaris
Nodi lymphatici axillares
Vv. intercostales posteriores
V. hemiazygos accessoria
V. hemiazygos
M. intercostalis internus
M. subcostalis
Diaphragma
Truncus intestinalis
Truncus lumbalis sinister
Nodi lymphatici lumbales postaortici
Aorta
Nodi lymphatici lumbales preaortici
Nodi lymphatici lumbales sinistri (aortici laterales)
Nodi lymphatici iliaca communes laterales
Aorta
M. psoas major
V. cava inferior
Ureter dexter
Nodi lymphatici iliaci communes
Nodi lymphatici iliaci externi
Lig. inguinale
V. iliaca externa
Peritoneum parietale
Nodi lymphatici inguinales profundi
Nodi lymphatici inguinales superficiales (superomediales)
M. rectus femoris
A. femoralis
V. femoralis
M. sartorius (перерезана)
V. saphena magna
Nodi lymphatici lumbales sinistri (aortici laterales)
Ureter sinister
A. iliaca communis sinistra
V. iliaca communis
Nodi lymphatici promontorii
Promontorium
Nodi lymphatici iliaci interni
Rectum
Nodi lymphatici inguinales superficiales (superomediales)
Nodi lymphatici inguinales superficiales (superolaterales)
Nodi lymphatici inguinales superficiales (inferiores)
Fascia lata
V. saphena magna
Scrotum
Vasa lymphatica superficialia

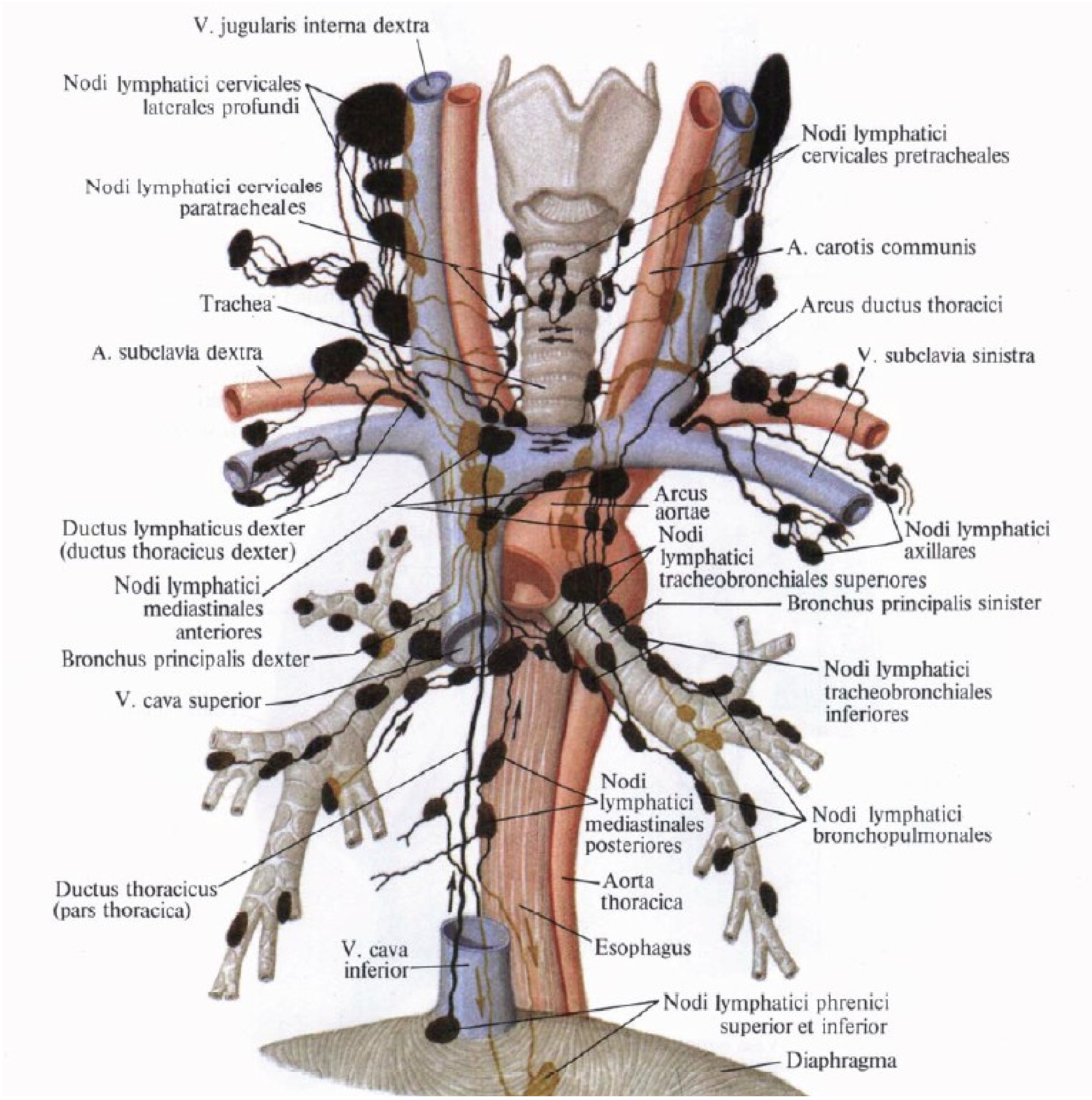


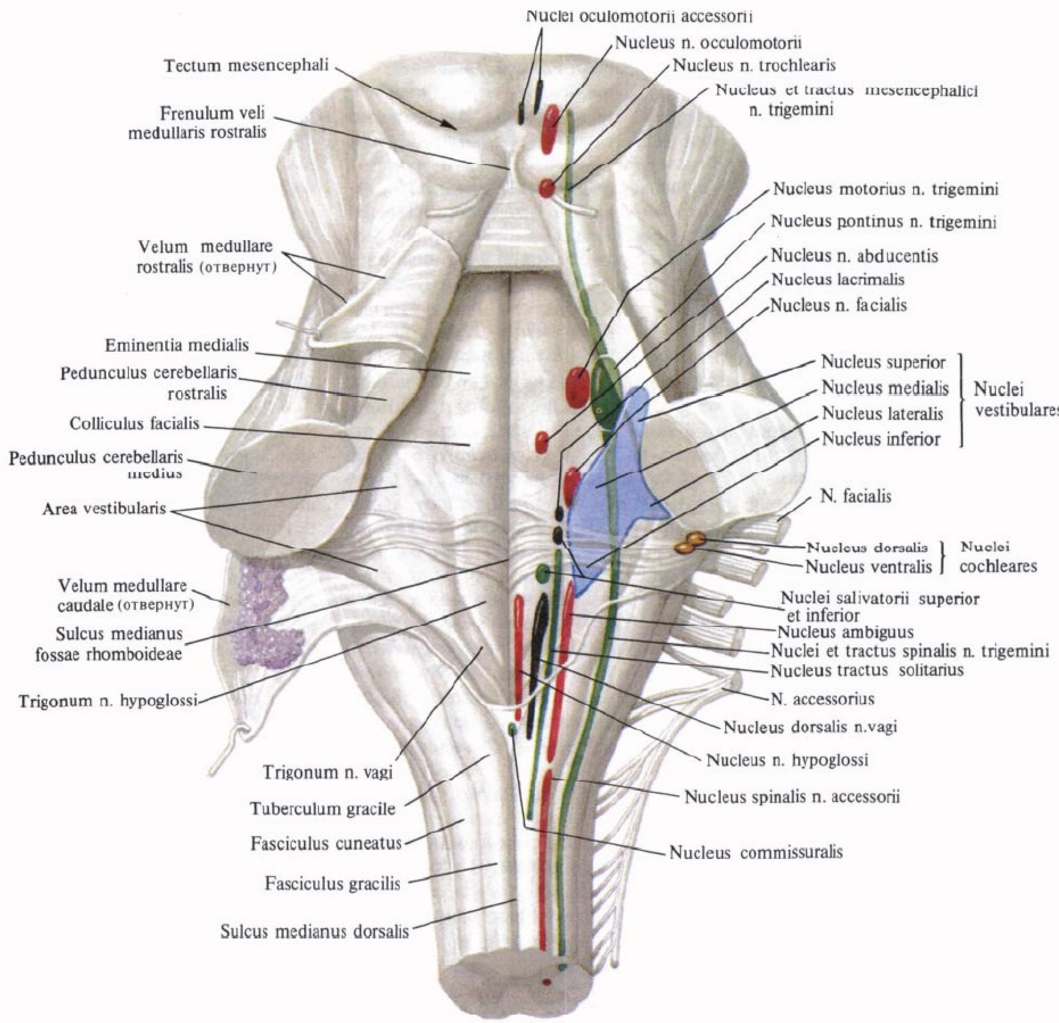
M. psoas major
V. cava inferior
Ureter dexter
Nodi lymphatici iliaci communes
Nodi lymphatici iliaci externi
Lig. inguinale
V. iliaca externa
Peritoneum parietale
Nodi lymphatici inguinales profundi
Nodi lymphatici inguinales superficiales (superomediales)
M. rectus femoris
A. femoralis
V. femoralis
M. sartorius (перерезана)
V. saphena magna
Aorta
Nodi lymphatici lumbales sinistri (aortici laterales)
Ureter sinister
A. iliaca communis sinistra
V. iliaca communis
Nodi lymphatici promontorii
Promontorium
Nodi lymphatici iliaci interni
Rectum
Nodi lymphatici inguinales superficiales (superomediales)
Nodi lymphatici inguinales superficiales (superolaterales)
Nodi lymphatici inguinales superficiales (inferiores)
Fascia lata
V. saphena magna
Scrotum
Vasa lymphatica superficialia


Nodi lymphatici colici dextri
Nodi lymphatici colici medii
Nodi lymphatici mesenterici superiores
Colon transversum
A. mesenterica superior
Glandula suprarenalis
Nodi lymphatici colici sinistri
Aorta
Ren sinister
Nodi limphatici iliaci communes
Intestinum tenue
Ren dexter
Nodi lymphatici lumbales
V. cava inferior
Ovarium
Nodi lymphatici sigmoidei
Nodi lymphatici rectales superiores
Nodi lymphatici mesenterici inferiores
Uterus
Vesica urinaria
Rectum
Tuba uterina

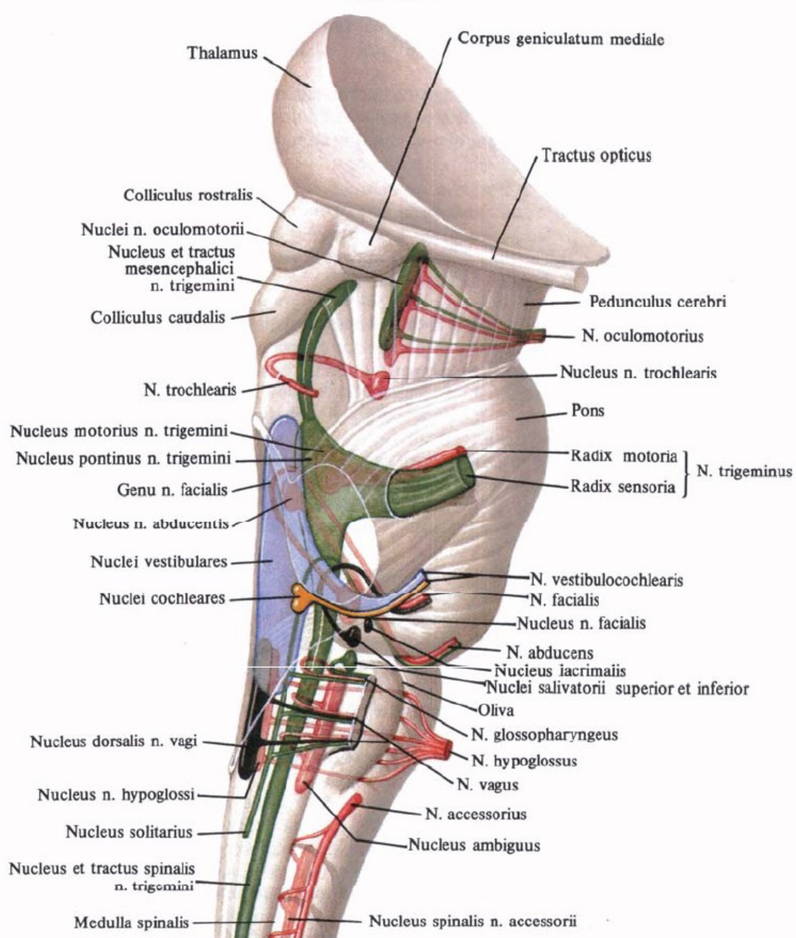

Nodi lymphatici celiaci
Lobus quadratus
Nodi lymphatici hepatici
Lobus hepaticus sinister
Vesica fellea
Nodi lymphatici gastrici sinistri
Ventriculus
A. lienalis (splenica)
Nodi lymphatici lienales (splenici)
Lien
Lobus hepaticus dexter
Glandula suprarenalis
A. gastroepiploica sinistra
Plexus lymfatici gastrici
Ren dexter
Nodi lymphatici gastroomentales dextri
Aorta
Ren sinister


Nodi lymphatici celiaci
Lobus quadratus
Lobus hepaticus sinister
Nodi lymphatici hepatici
Vesica fellea
Nodi lymphatici gastrici sinistri
Ventriculus
A. lienalis (splenica)
Nodi lymphatici lienales (splenici)
Lien
Lobus hepaticus dexter
Glandula suprarenalis
A. gastroepiploica sinistra
Plexus lymfatici gastrici
Ren dexter
Nodi lymphatici gastroomentales dextri
Aorta
Ren sinister
Nodi lymphatici lumbales
A. gastroepiploica dextra
V. cava inferior

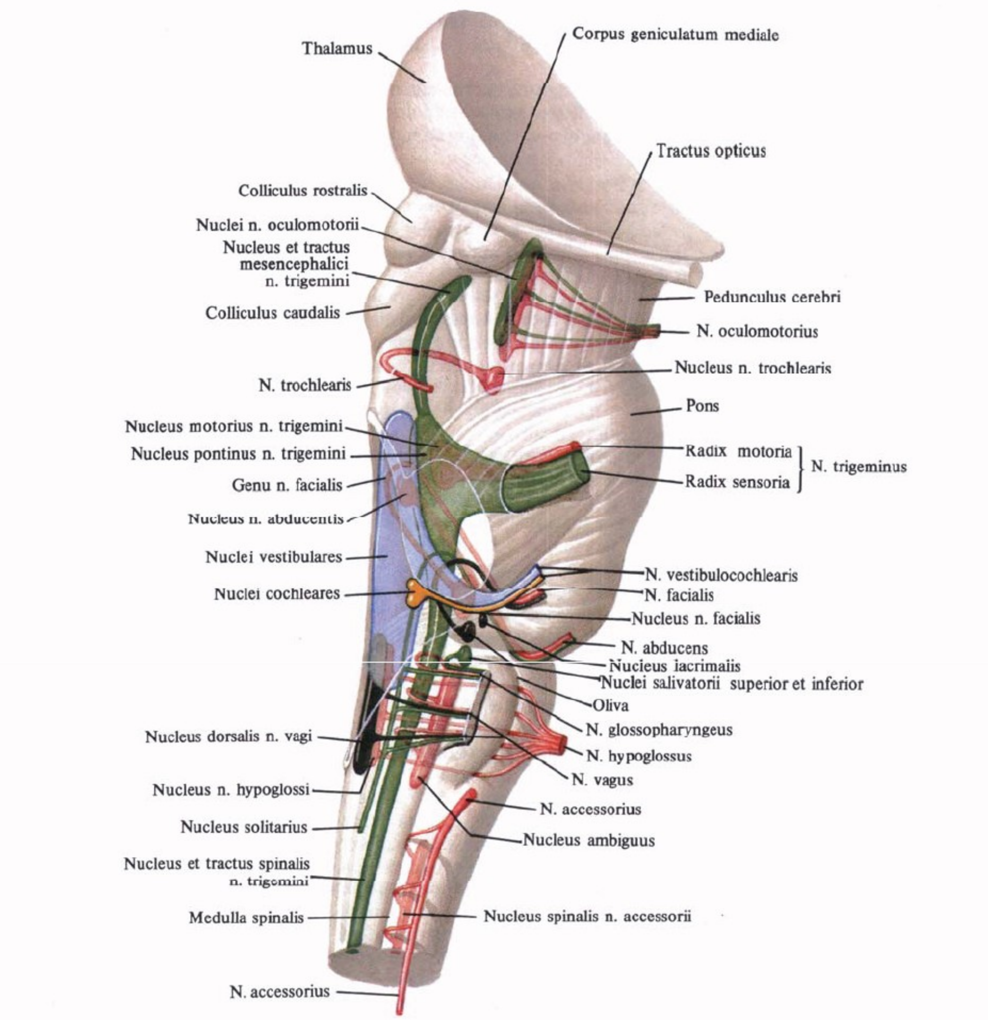

V. jugularis interna dextra
Nodi lymphatici cervicales laterales profundi
Nodi lymphatici cervicales pretracheales
Nodi lymphatici cervicales paratracheales
A. carotis communis
Trachea
Arcus ductus thoracici
A. subclavia dextra
V. subclavia sinistra
Arcus aortae
Ductus lymphaticus dexter (ductus thoracicus dexter)
Nodi lymphatici tracheobronchiales superiores
Nodi lymphatici axillares
Nodi lymphatici mediastinales anteriores
Bronchus principalis sinister
Bronchus principalis dexter
Nodi lymphatici tracheobronchiales inferiores
V. cava superior
Nodi lymphatici mediastinales posteriores
Nodi lymphatici bronchopulmonales
Ductus thoracicus (pars thoracica)
Aorta thoracica
Esophagus
V. cava inferior
Nodi lymphatici phrenici superior et inferior
Diaphragma



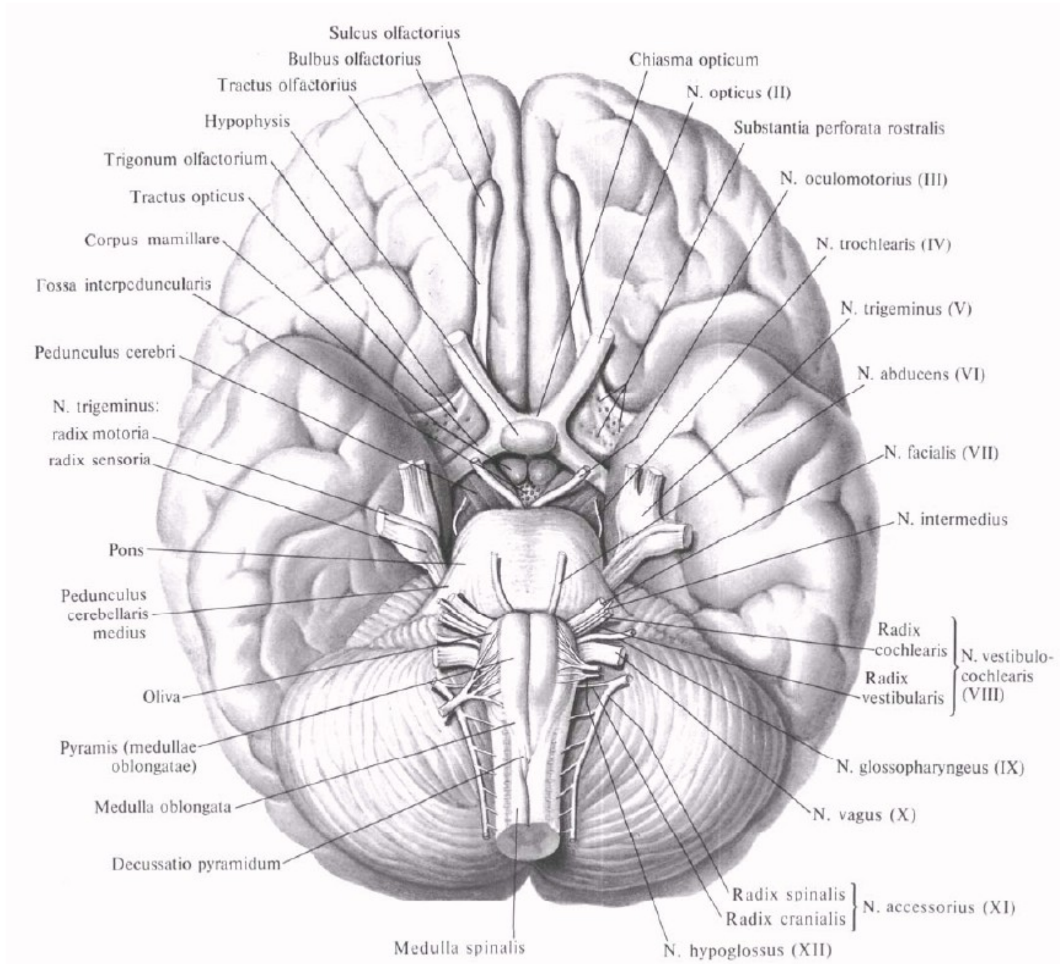
Nuclei oculomotorii accessorii
Nucleus n. occulomotorii
Nucleus n. trochlearis
Nucleus et tractus mesencephalici n. trigemini
Tectum mesencephali
Frenulum veli medullaris rostralis
Nucleus motorius n. trigemini
Nucleus pontinus n. trigemini
Nucleus n. abducentis
Nucleus lacrimalis
Nucleus n. facialis
Velum medullare rostralis (отвернут)
Eminentia medialis
Pedunculus cerebellaris rostralis
Colliculus facialis
Pedunculus cerebellaris medius
Area vestibularis
Nucleus superior
Nucleus medialis
Nucleus lateralis
Nucleus inferior
Nuclei vestibulares
N. facialis
Nucleus dorsalis
Nucleus ventralis
Nuclei cochleares
Velum medullare caudale (отвернут)
Sulcus medianus fossae rhomboideae
Trigonum n. hypoglossi
Nuclei salivatorii superior et inferior
Nucleus ambiguus
Nuclei et tractus spinalis n. trigemini
Nucleus tractus solitarius
N. accessorius
Nucleus dorsalis n.vagi
Nucleus n. hypoglossi
Trigonum n. vagi
Tuberculum gracile
Fasciculus cuneatus
Fasciculus gracilis
Sulcus medianus dorsalis
Nucleus spinalis n. accessorii
Nucleus commissuralis

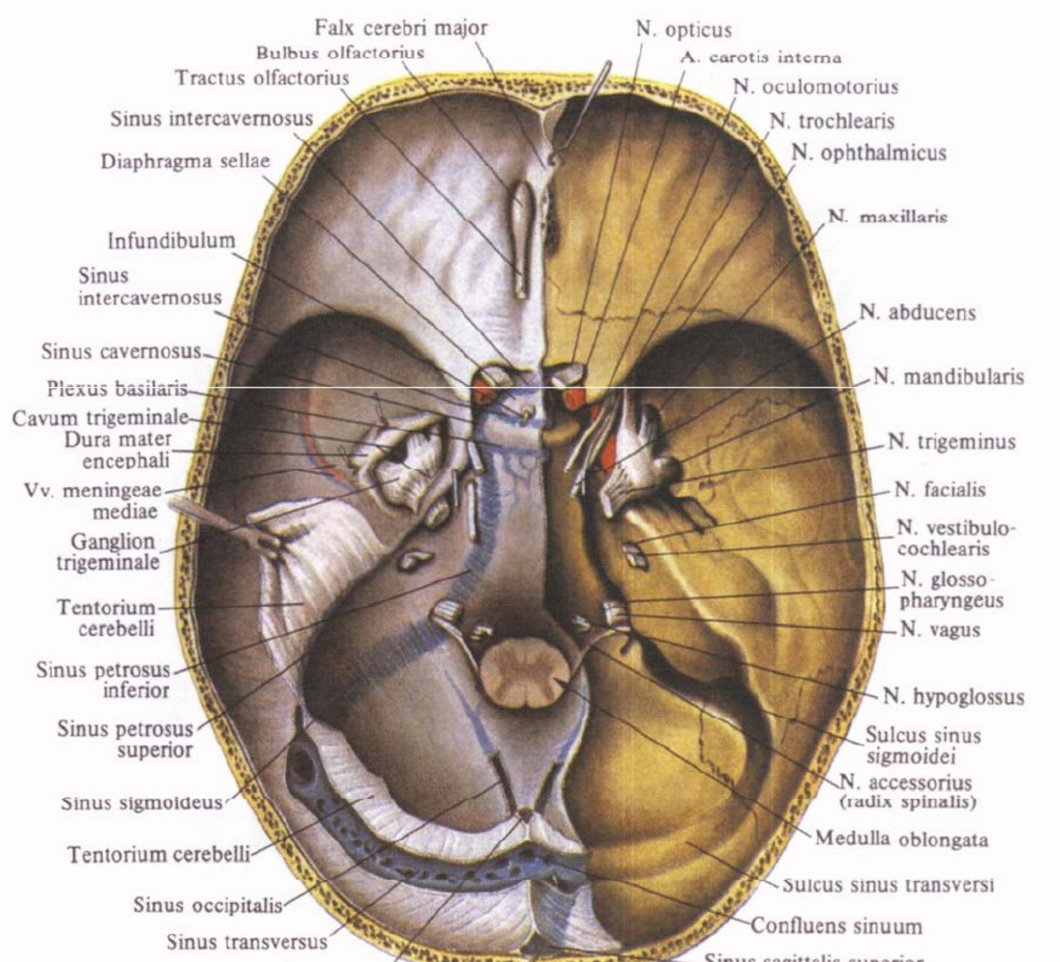


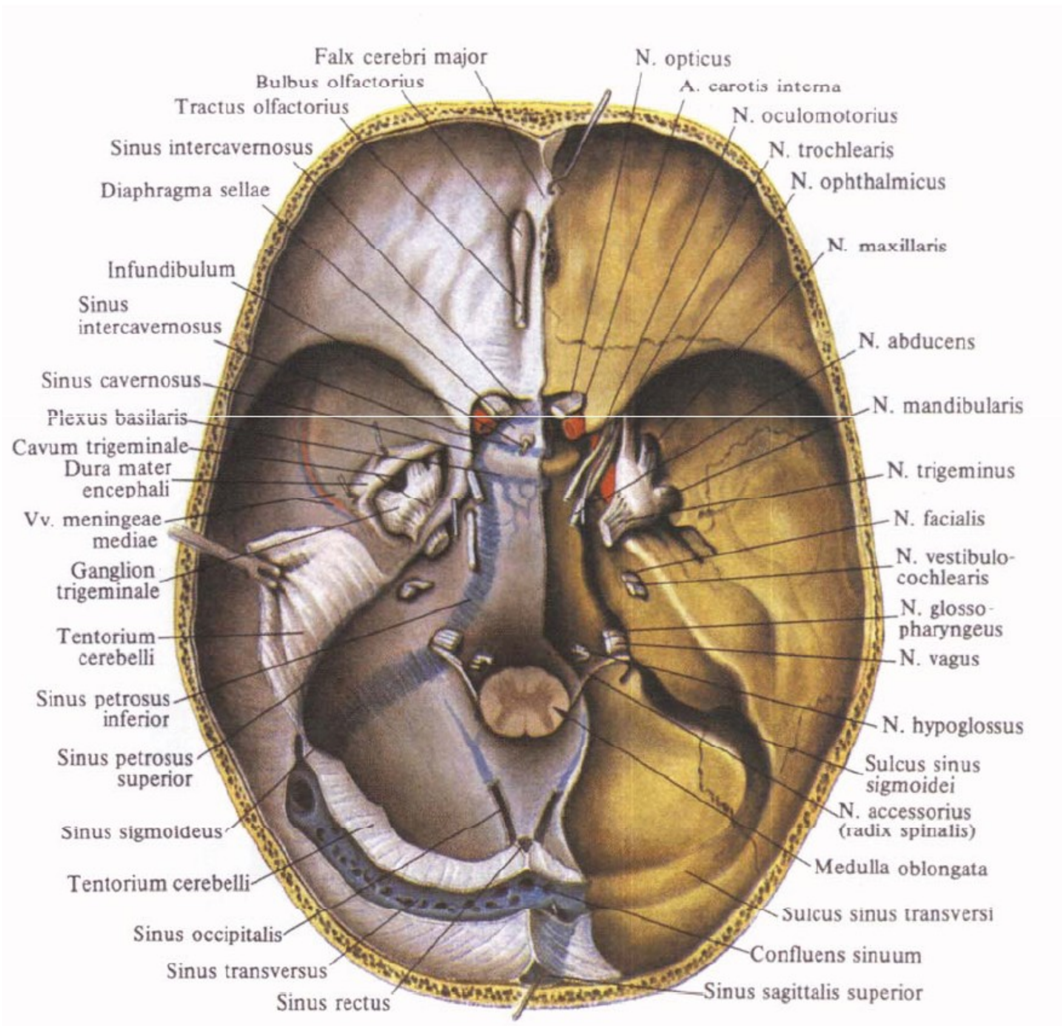
Thalamus
Corpus geniculatum mediale
Tractus opticus
Colliculus rostralis
Nuclei n. oculomotorii
Nucleus et tractus mesencephalici n. trigemini
Colliculus caudalis
Pedunculus cerebri
N. oculomotorius
N. trochlearis
Nucleus n. trochlearis
Pons
Nucleus motorius n. trigemini
Nucleus pontinus n. trigemini
Radix motoria
Radix sensoria
N. trigeminus
Genu n. facialis
Nucleus n. abducentis
Nuclei vestibulares
Nuclei cochleares
N. vestibulocochlearis
N. facialis
Nucleus n. facialis
N. abducens
Nucleus lacrimalis
Nuclei salivatorii superior et inferior
Oliva
N. glossopharyngeus
Nucleus dorsalis n. vagi
N. hypoglossus
N. vagus
Nucleus n. hypoglossi
N. accessorius
Nucleus solitarius
Nucleus ambiguus
Nucleus et tractus spinalis n. trigemini
Medulla spinalis
Nucleus spinalis n. accessorii



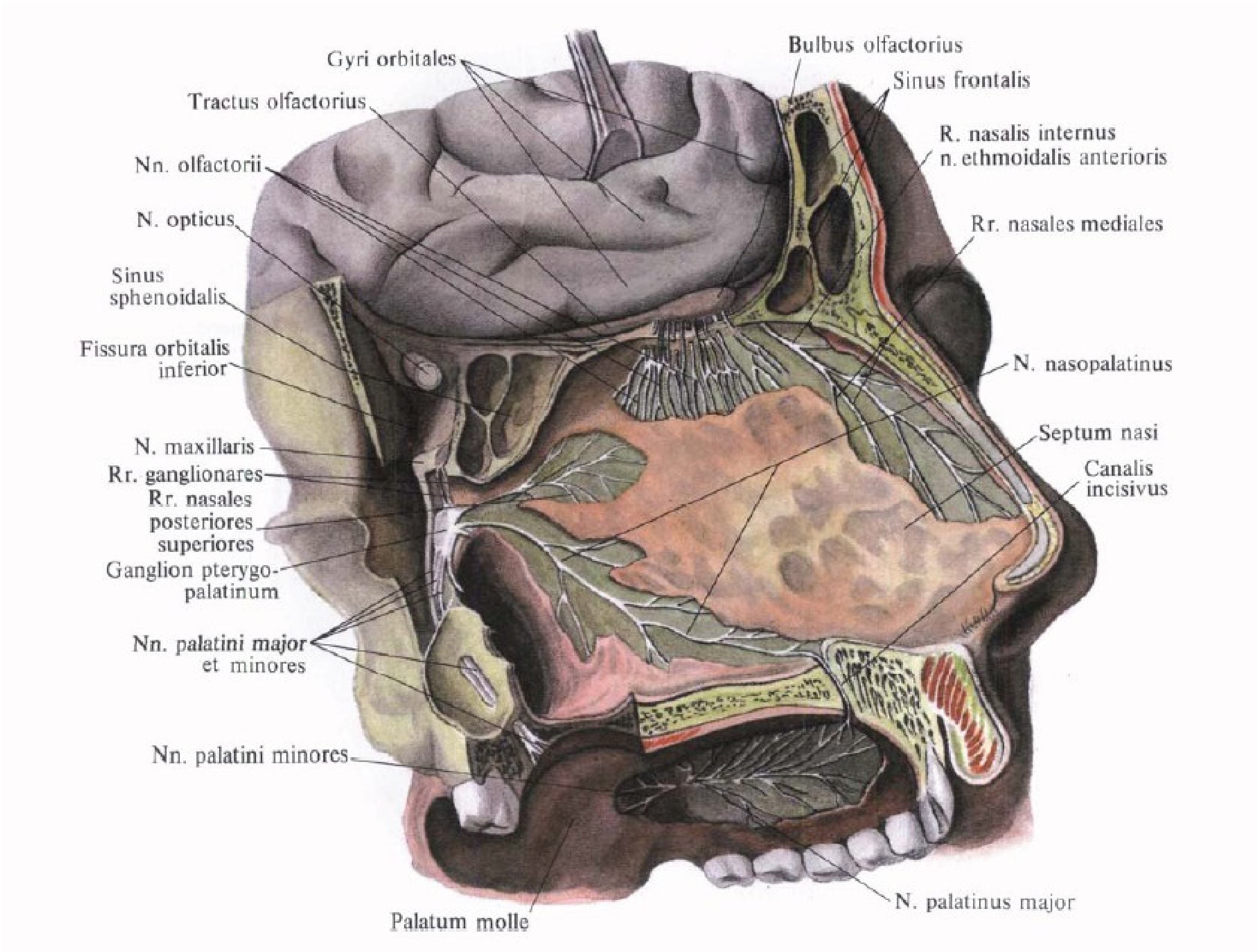
Thalamus
Corpus geniculatum mediale
Tractus opticus
Colliculus rostralis
Nuclei n. oculomotorii
Nucleus et tractus mesencephalici n. trigemini
Colliculus caudalis
Pedunculus cerebri
N. oculomotorius
N. trochlearis
Nucleus n. trochlearis
Pons
Nucleus motorius n. trigemini
Nucleus pontinus n. trigemini
Radix motoria
Radix sensoria
N. trigeminus
Genu n. facialis
Nucleus n. abducentis
Nuclei vestibulares
N. vestibulocochlearis
Nuclei cochleares
N. facialis
Nucleus n. facialis
N. abducens
Nucleus lacrimalis
Nuclei salivatorii superior et inferior
Oliva
N. glossopharyngeus
Nucleus dorsalis n. vagi
N. hypoglossus
N. vagus
Nucleus n. hypoglossi
N. accessorius
Nucleus solitarius
Nucleus ambiguus
Nucleus et tractus spinalis n. trigemini
Medulla spinalis
Nucleus spinalis n. accessorii
N. accessorius


Sulcus olfactorius
Bulbus olfactorius
Tractus olfactorius
Hypophysis
Trigonum olfactorium
Tractus opticus
Corpus mamillare
Fossa interpeduncularis
Pedunculus cerebri
N. trigeminus:
radix motoria
radix sensoria
Pons
Pedunculus cerebellaris medius
Oliva
Pyramis (medullae oblongatae)
Medulla oblongata
Decussatio pyramidum
Medulla spinalis
Chiasma opticum
N. opticus (II)
Substantia perforata rostralis
N. oculomotorius (III)
N. trochlearis (IV)
N. trigeminus (V)
N. abducens (VI)
N. facialis (VII)
N. intermedius
Radix cochlearis
Radix vestibularis
N. vestibulocochlearis (VIII)
N. glossopharyngeus (IX)
N. vagus (X)
Radix spinalis
Radix cranialis
N. accessorius (XI)
N. hypoglossus (XII)

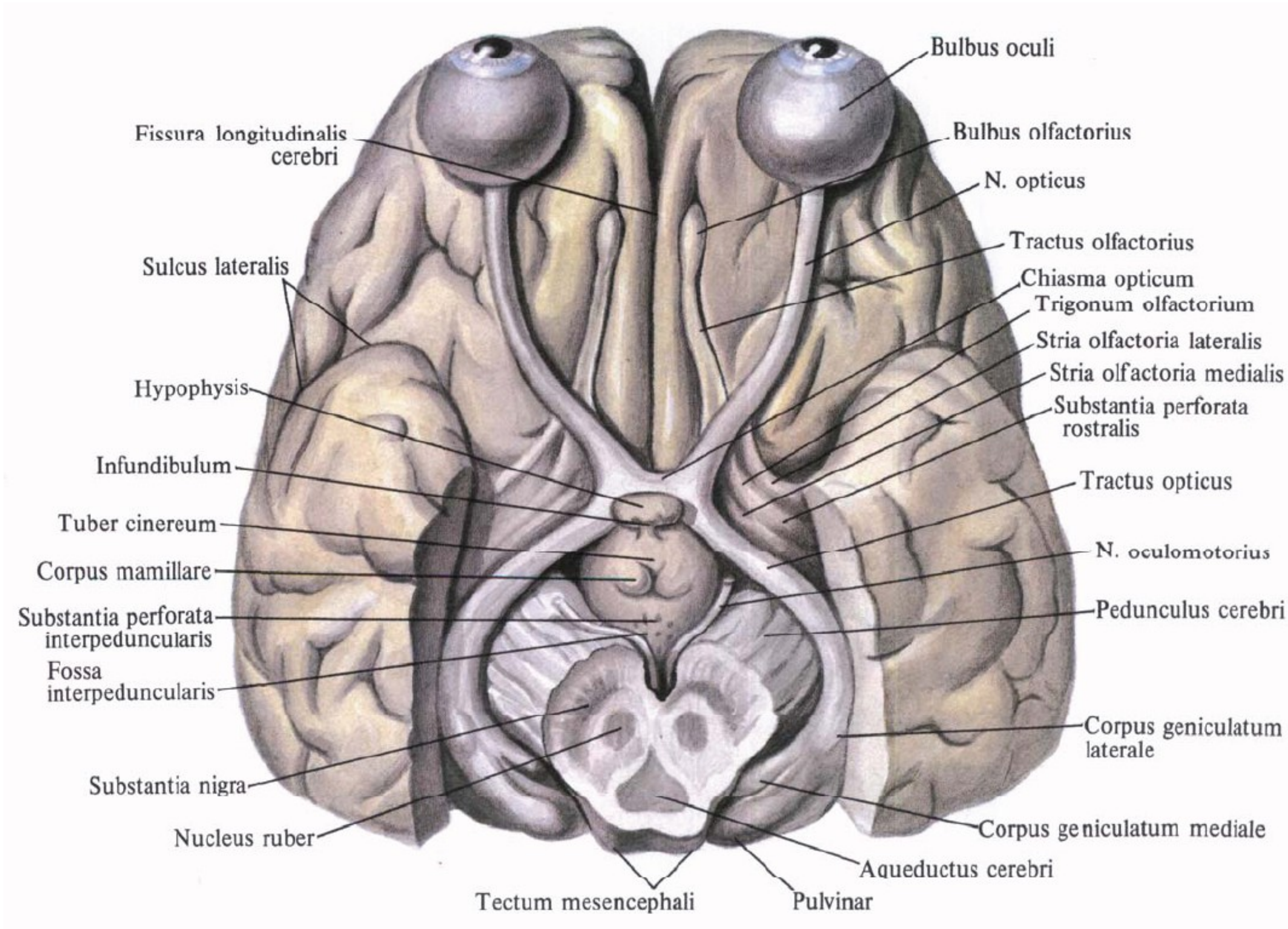

Falx cerebri major
Bulbus olfactorius
Tractus olfactorius
Sinus intercavernosus
Diaphragma sellae
Infundibulum
Sinus intercavernosus
Sinus cavernosus
Plexus basilaris
Cavum trigeminale
Dura mater encephali
Vv. meningeae mediae
Ganglion trigeminale
Tentorium cerebelli
Sinus petrosus inferior
Sinus petrosus superior
Sinus sigmoideus
Tentorium cerebelli
Sinus occipitalis
Sinus transversus
N. opticus
A. carotis interna
N. oculomotorius
N. trochlearis
N. ophthalmicus
N. maxillaris
N. abducens
N. mandibularis
N. trigeminus
N. facialis
N. vestibulocochlearis
N. glossopharyngeus
N. vagus
N. hypoglossus
Sulcus sinus sigmoidei
N. accessorius (radix spinalis)
Medulla oblongata
Sulcus sinus transversi
Confluens sinuum



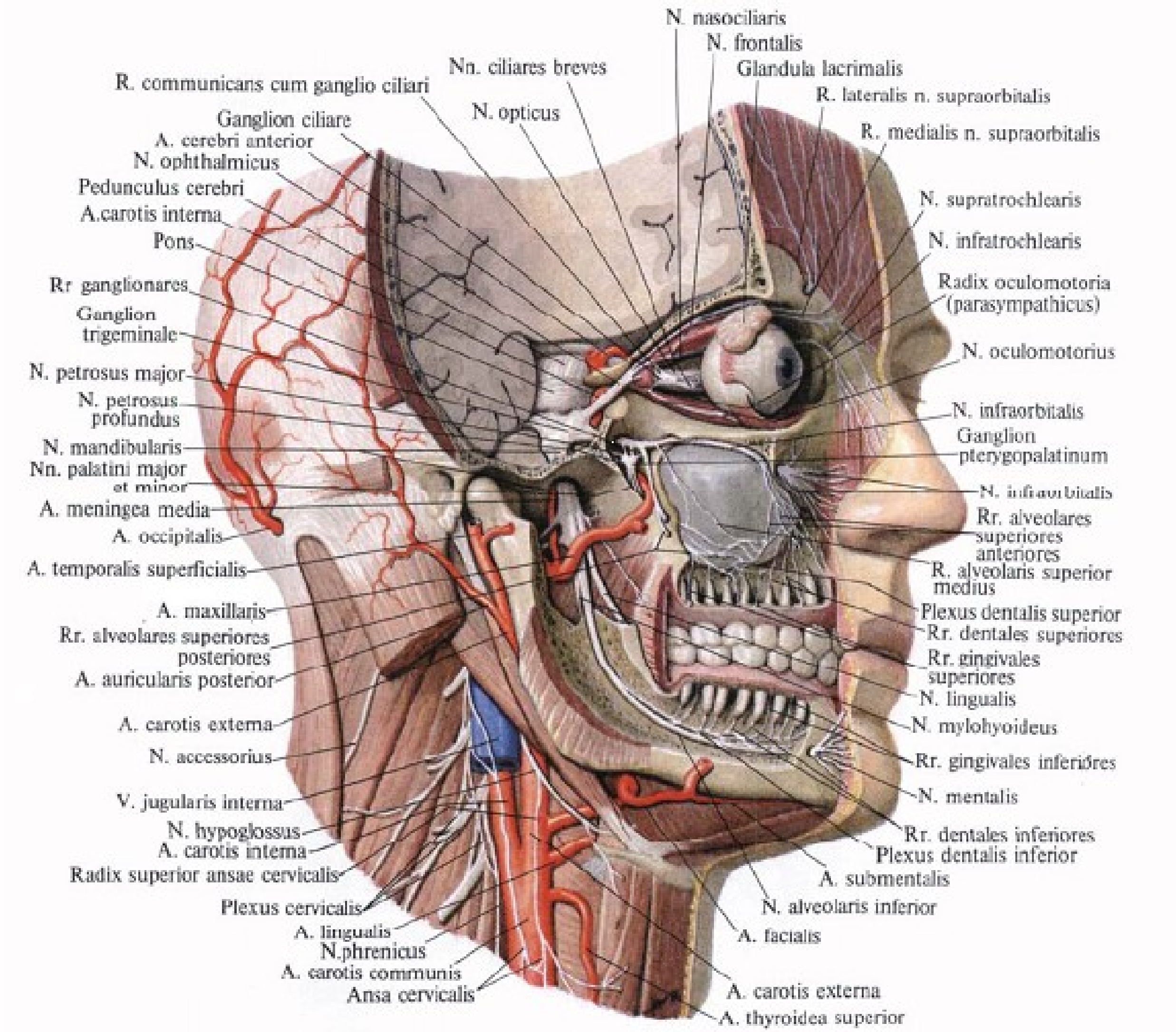
Falx cerebri major
Bulbus olfactorius
Tractus olfactorius
Sinus intercavernosus
Diaphragma sellae
Infundibulum
Sinus intercavernosus
Sinus cavernosus
Plexus basilaris
Cavum trigeminale
Dura mater encephali
Vv. meningeae mediae
Ganglion trigeminale
Tentorium cerebelli
Sinus petrosus inferior
Sinus petrosus superior
Sinus sigmoideus
Tentorium cerebelli
Sinus occipitalis
Sinus transversus
Sinus rectus
N. opticus
A. carotis interna
N. oculomotorius
N. trochlearis
N. ophthalmicus
N. maxillaris
N. abducens
N. mandibularis
N. trigeminus
N. facialis
N. vestibulocochlearis
N. glossopharyngeus
N. vagus
N. hypoglossus
Sulcus sinus sigmoidei
N. accessorius (radix spinalis)
Medulla oblongata
Sulcus sinus transversi
Confluens sinuum
Sinus sagittalis superior

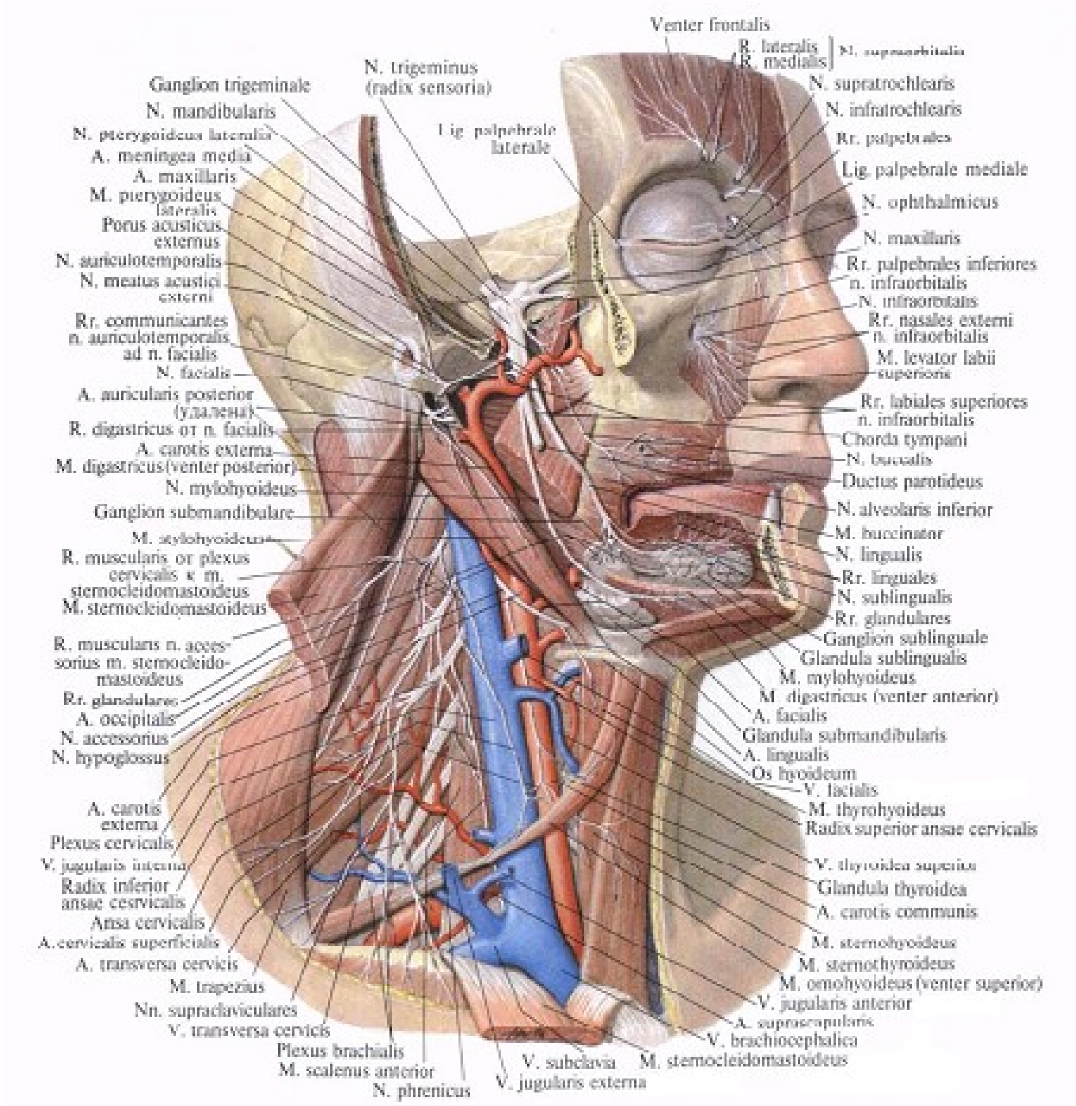


Gyri orbitales
Bulbus olfactorius
Sinus frontalis
Tractus olfactorius
R. nasalis internus
n. ethmoidalis anterioris
Nn. olfactorii
N. opticus
Rr. nasales mediales
Sinus
sphenoidalis
Fissura orbitalis
inferior
N. nasopalatinus
N. maxillaris
Septum nasi
Rr. ganglionares
Canalis
incisivus
Rr. nasales
posteriores
superiores
Ganglion pterygo-
palatinum
Nn. palatini major
et minores
Nn. palatini minores
N. palatinus major
Palatum molle

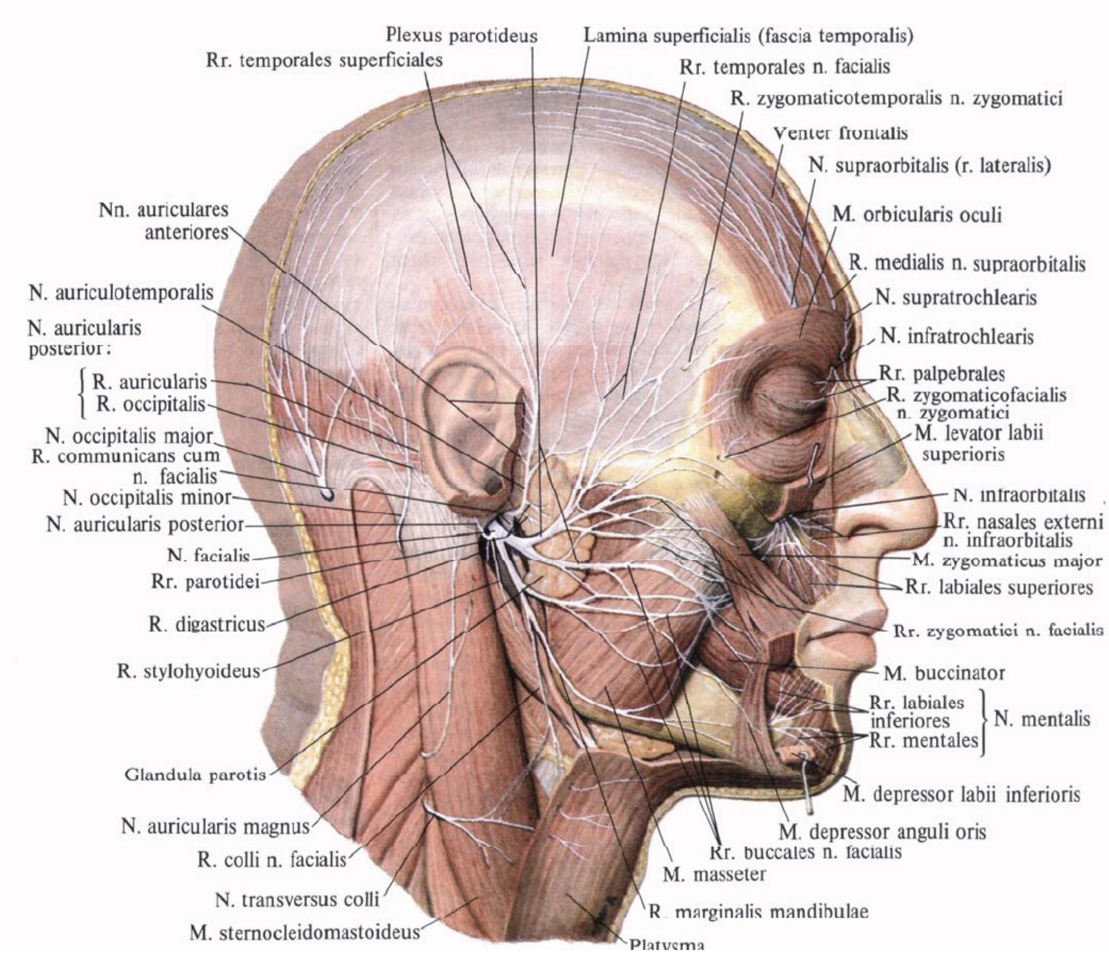


Bulbus oculi
Fissura longitudinalis cerebri
Bulbus olfactorius
N. opticus
Tractus olfactorius
Sulcus lateralis
Chiasma opticum
Trigonum olfactorium
Stria olfactoria lateralis
Stria olfactoria medialis
Hypophysis
Substantia perforata rostralis
Infundibulum
Tractus opticus
Tuber cinereum
N. oculomotorius
Corpus mamillare
Substantia perforata interpeduncularis
Pedunculus cerebri
Fossa interpeduncularis
Corpus geniculatum laterale
Substantia nigra
Nucleus ruber
Corpus geniculatum mediale
Aqueductus cerebri
Tectum mesencephali
Pulvinar

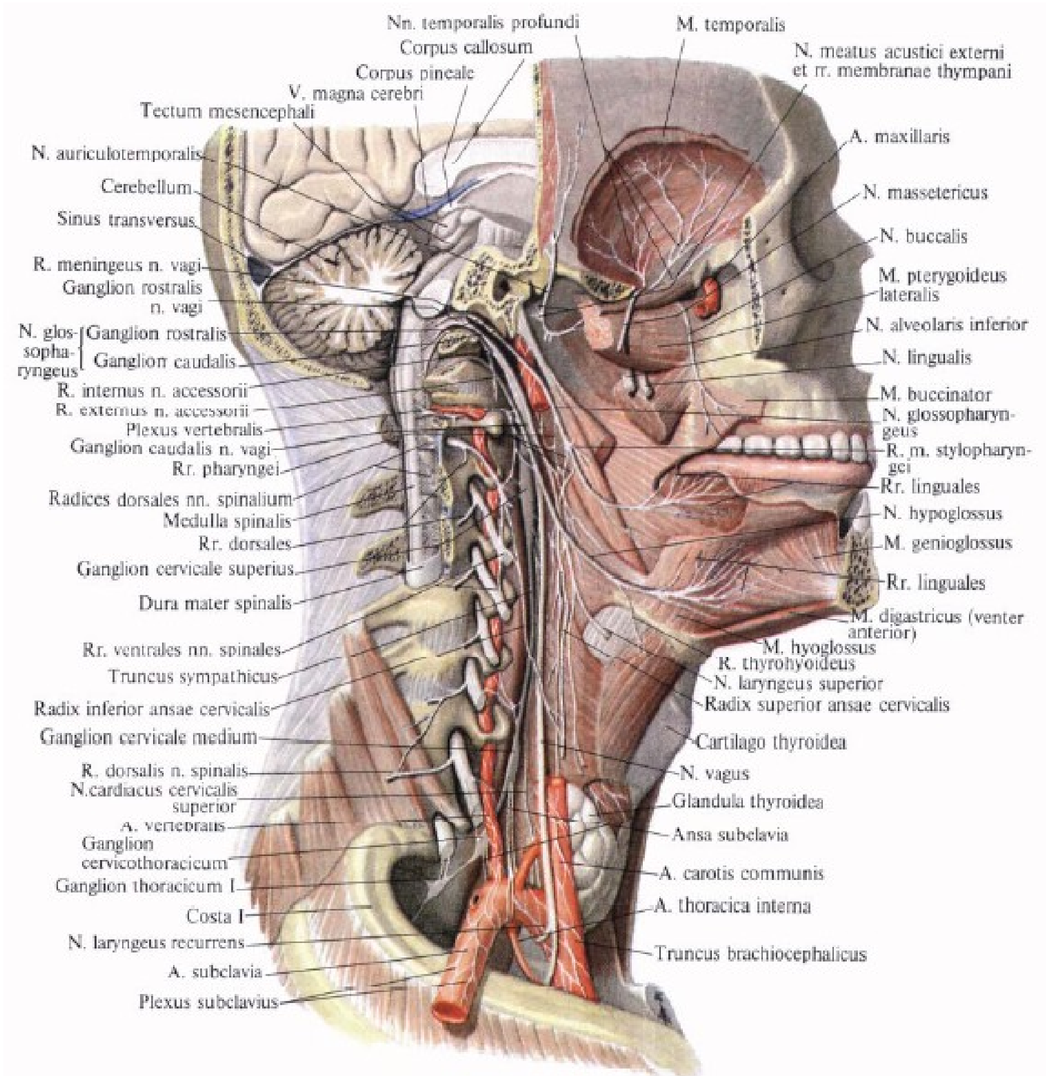

N. nasociliaris
N. frontalis
Glandula lacrimalis
R. lateralis n. supraorbitalis
R. medialis n. supraorbitalis
Nn. ciliares breves
R. communicans cum ganglio ciliari
N. opticus
Ganglion ciliare
A. cerebri anterior
N. ophthalmicus
Pedunculus cerebri
A.carotis interna
Pons
Rr ganglionares
Ganglion trigeminale
N. petrosus major
N. petrosus profundus
N. mandibularis
Nn. palatini major et minor
A. meningea media
A. occipitalis
A. temporalis superficialis
A. maxillaris
Rr. alveolares superiores posteriores
A. auricularis posterior
A. carotis externa
N. accessorius
V. jugularis interna
N. hypoglossus
A. carotis interna
Radix superior ansae cervicalis
Plexus cervicalis
A. lingualis
N.phrenicus
A. carotis communis
Ansa cervicalis
N. supratrochlearis
N. infratrochlearis
Radix oculomotoria (parasympathicus)
N. oculomotorius
N. infraorbitalis
Ganglion pterygopalatinum
N. infraorbitalis
Rr. alveolares superiores anteriores
R. alveolaris superior medius
Plexus dentalis superior
Rr. dentales superiores
Rr. gingivales superiores
N. lingualis
N. mylohyoideus
Rr. gingivales inferiores
N. mentalis
Rr. dentales inferiores
Plexus dentalis inferior
A. submentalis
N. alveolaris inferior
A. facialis
A. carotis externa
A. thyroidea superior

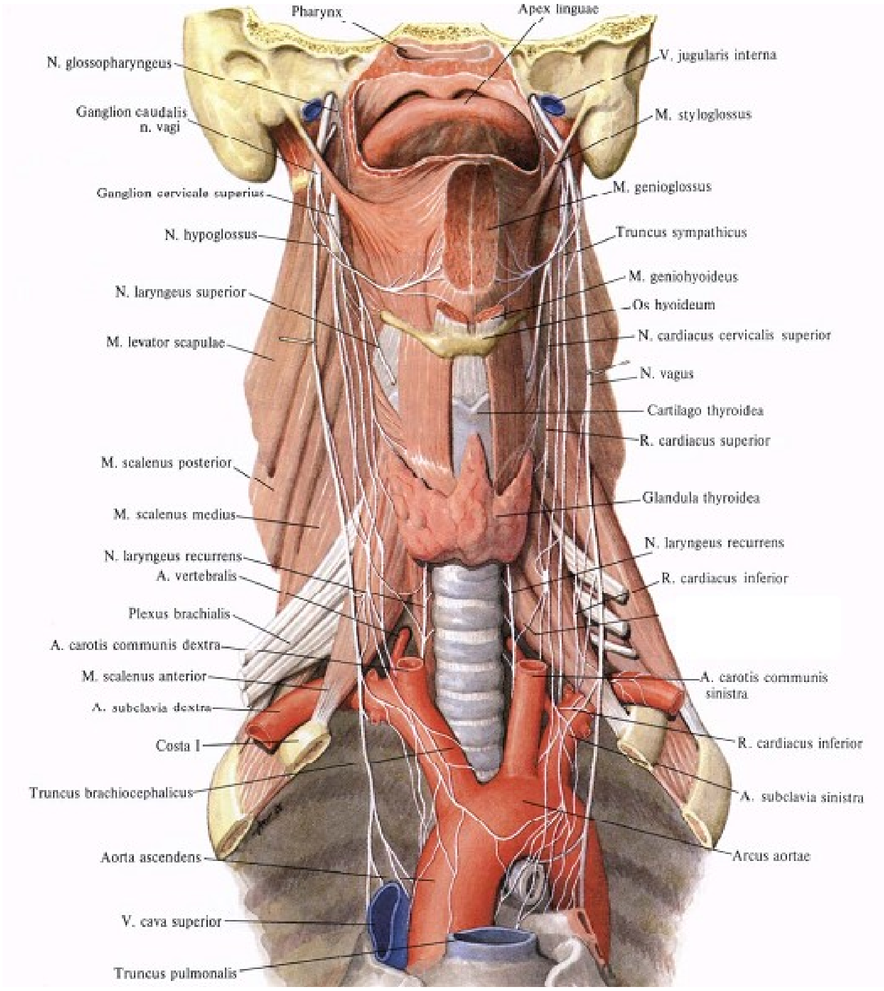


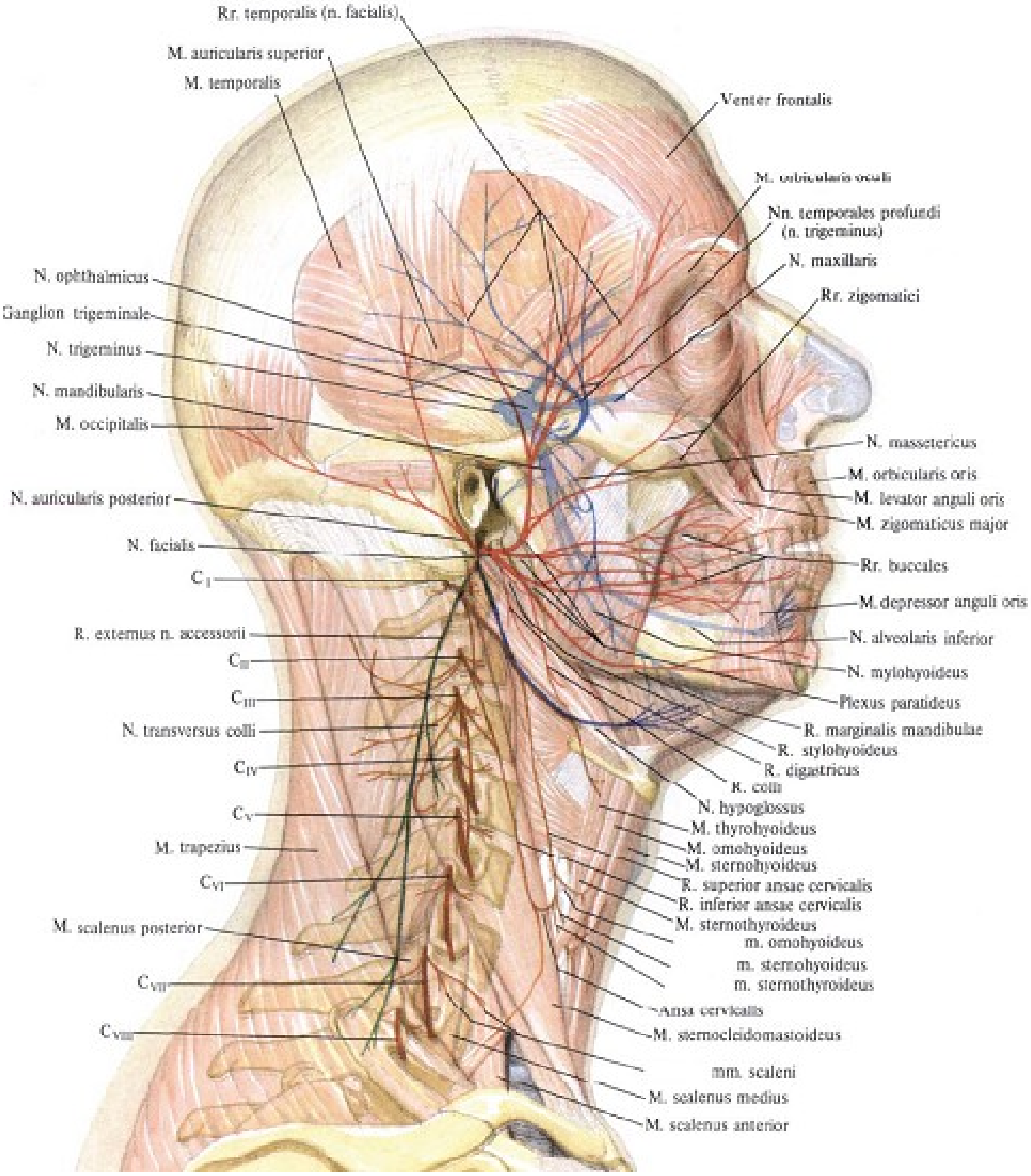
Venter frontalis
R. lateralis
R. medialis
N. supraorbitalis
N. trigeminus
(radix sensoria)
Ganglion trigeminale
N. mandibularis
N. pterygoideus lateralis
A. meningea media
A. maxillaris
M. pterygoideus
lateralis
Porus acusticus
externus
N. auriculotemporalis
N. meatus acustici
externi
Rr. communicantes
n. auriculotemporalis
ad n. facialis
N. facialis
A. auricularis posterior
(удалена)
R. digastricus от n. facialis
A. carotis externa
M. digastricus (venter posterior)
N. mylohyoideus
Ganglion submandibulare
M. stylohyoideus
R. muscularis от plexus
cervicalis к m.
sternocleidomastoideus
M. sternocleidomastoideus
R. muscularis n. accessorius m. sternocleidomastoideus
Rr. glandulares
A. occipitalis
N. accessorius
N. hypoglossus
A. carotis
externa
Plexus cervicalis
V. jugularis interna
Radix inferior
ansae cesrvicalis
Ansa cervicalis
A. cervicalis superficialis
A. transversa cervicis
M. trapezius
Nn. supraclaviculares
V. transversa cervicis
Plexus brachialis
M. scalenus anterior
N. phrenicus
Lig. palpebrale
laterale
N. supratrochlearis
N. infratrochlearis
Rr. palpebrales
Lig. palpebrale mediale
N. ophthalmicus
N. maxillaris
Rr. palpebrales inferiores
n. infraorbitalis
N. infraorbitalis
Rr. nasales externi
n. infraorbitalis
M. levator labii
superioris
Rr. labiales superiores
n. infraorbitalis
Chorda tympani
N. buccalis
Ductus parotideus
N. alveolaris inferior
M. buccinator
N. lingualis
Rr. linguales
N. sublingualis
Rr. glandulares
Ganglion sublinguale
Glandula sublingualis
M. mylohyoideus
M. digastricus (venter anterior)
A. facialis
Glandula submandibularis
A. lingualis
Os hyoideum
V. facialis
M. thyrohyoideus
Radix superior ansae cervicalis
V. thyroidea superior
Glandula thyroidea
A. carotis communis
M. sternohyoideus
M. sternothyroideus
M. omohyoideus (venter superior)
V. jugularis anterior
A. suprascapularis
V. brachiocephalica
M. sternocleidomastoideus
V. subclavia
V. jugularis externa



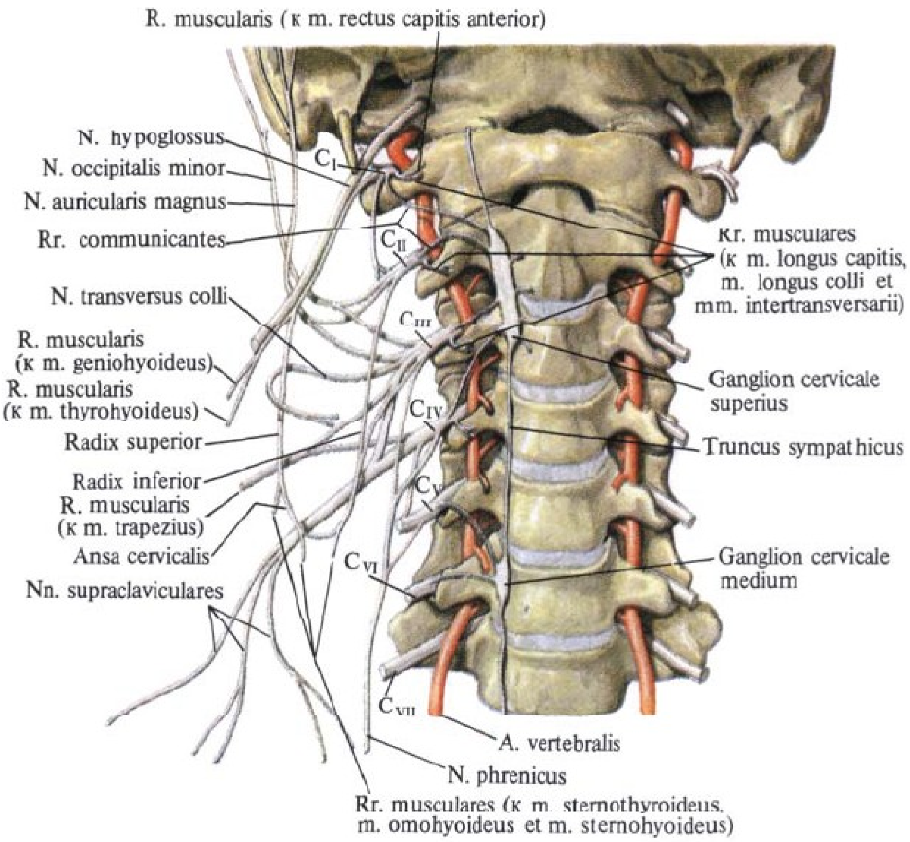
Plexus parotideus
Lamina superficialis (fascia temporalis)
Rr. temporales superficiales
Rr. temporales n. facialis
R. zygomaticotemporalis n. zygomatici
Venter frontalis
N. supraorbitalis (r. lateralis)
M. orbicularis oculi
R. medialis n. supraorbitalis
N. supratrochlearis
N. infratrochlearis
Rr. palpebrales
R. zygomaticofacialis n. zygomatici
M. levator labii superioris
N. infraorbitalis
Rr. nasales externi n. infraorbitalis
M. zygomaticus major
Rr. labiales superiores
Rr. zygomatici n. facialis
M. buccinator
Rr. labiales inferiores
Rr. mentales
N. mentalis
M. depressor labii inferioris
M. depressor anguli oris
Rr. buccales n. facialis
M. masseter
R. marginalis mandibulae
Platysma
Nn. auriculares anteriores
N. auriculotemporalis
N. auricularis posterior:
R. auricularis
R. occipitalis
N. occipitalis major
R. communicans cum n. facialis
N. occipitalis minor
N. auricularis posterior
N. facialis
Rr. parotidei
R. digastricus
R. stylohyoideus
Glandula parotis
N. auricularis magnus
R. colli n. facialis
N. transversus colli
M. sternocleidomastoideus


Nn. temporalis profundi
M. temporalis
Corpus callosum
N. meatus acustici externi
et rr. membranae thympani
Corpus pineale
V. magna cerebri
Tectum mesencephali
A. maxillaris
N. auriculotemporalis
Cerebellum
N. massetericus
Sinus transversus
N. buccalis
R. meningeus n. vagi
M. pterygoideus
lateralis
Ganglion rostralis
n. vagi
N. glos-
sopha-
ryngeus
Ganglion rostralis
Ganglion caudalis
N. alveolaris inferior
N. lingualis
R. internus n. accessorii
M. buccinator
R. externus n. accessorii
N. glossopharyn-
geus
Plexus vertebralis
Ganglion caudalis n. vagi
R. m. stylopharyn-
gei
Rr. pharyngei
Rr. linguales
Radices dorsales nn. spinalium
Medulla spinalis
N. hypoglossus
Rr. dorsales
M. genioglossus
Ganglion cervicale superius
Rr. linguales
Dura mater spinalis
M. digastricus (venter
anterior)
M. hyoglossus
Rr. ventrales nn. spinales
R. thyrohyoideus
Truncus sympathicus
N. laryngeus superior
Radix inferior ansae cervicalis
Radix superior ansae cervicalis
Ganglion cervicale medium
Cartilago thyroidea
R. dorsalis n. spinalis
N. vagus
N.cardiacus cervicalis
superior
Glandula thyroidea
A. vertebralis
Ansa subclavia
Ganglion
cervicothoracicum
A. carotis communis
Ganglion thoracicum I
A. thoracica interna
Costa I
N. laryngeus recurrens
Truncus brachiocephalicus
A. subclavia
Plexus subclavius

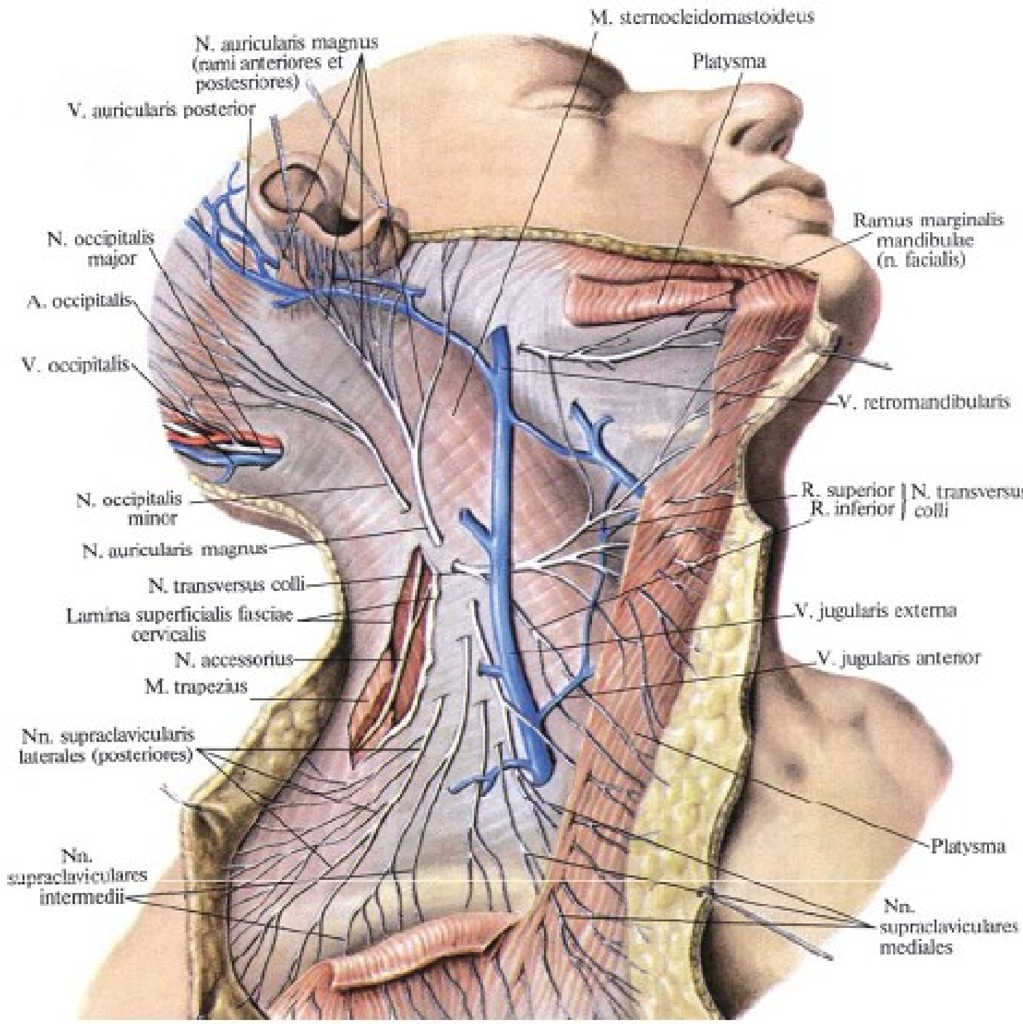

Pharynx
Apex linguae
N. glossopharyngeus
V. jugularis interna
Ganglion caudalis n. vagi
M. styloglossus
Ganglion cervicale superius
M. genioglossus
N. hypoglossus
Truncus sympathicus
N. laryngeus superior
M. geniohyoideus
Os hyoideum
M. levator scapulae
N. cardiacus cervicalis superior
N. vagus
Cartilago thyroidea
R. cardiacus superior
M. scalenus posterior
Glandula thyroidea
M. scalenus medius
N. laryngeus recurrens
N. laryngeus recurrens
A. vertebralis
R. cardiacus inferior
Plexus brachialis
A. carotis communis dextra
M. scalenus anterior
A. carotis communis sinistra
A. subclavia dextra
R. cardiacus inferior
Costa I
Truncus brachiocephalicus
A. subclavia sinistra
Aorta ascendens
Arcus aortae
V. cava superior
Truncus pulmonalis



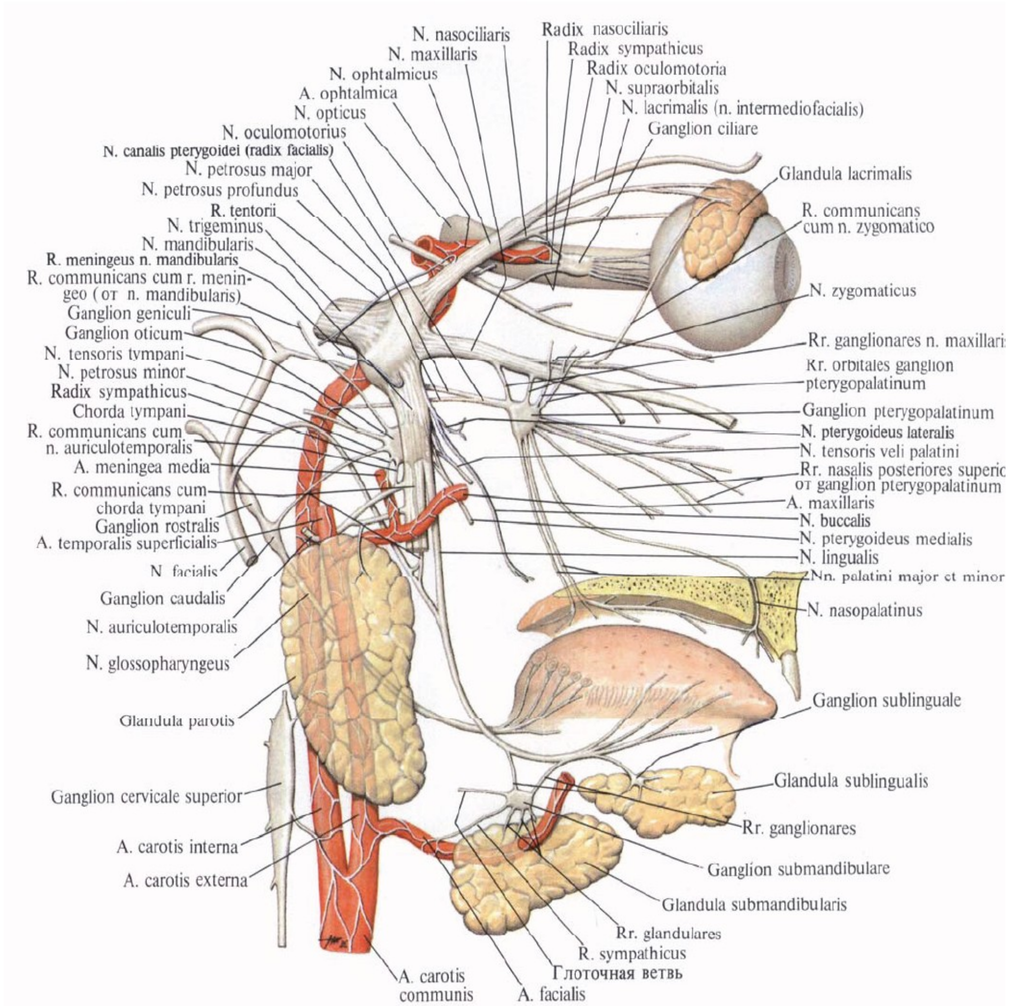
Rr. temporalis (n. facialis)
M. auricularis superior
M. temporalis
Venter frontalis
M. orbicularis oculi
Nn. temporales profundi (n. trigeminus)
N. maxillaris
Rr. zigomatici
N. ophthalmicus
Ganglion trigeminale
N. trigeminus
N. mandibularis
M. occipitalis
N. massetericus
M. orbicularis oris
M. levator anguli oris
M. zigomaticus major
N. auricularis posterior
N. facialis
Rr. buccales
M. depressor anguli oris
R. externus n. accessorii
N. alveolaris inferior
N. mylohyoideus
Plexus paratideus
N. transversus colli
R. marginalis mandibulae
R. stylohyoideus
R. digastricus
R. colli
N. hypoglossus
M. thyrohyoideus
M. omohyoideus
M. sternohyoideus
M. trapezius
R. superior ansae cervicalis
R. inferior ansae cervicalis
M. sternothyroideus
M. scalenus posterior
m. omohyoideus
m. sternohyoideus
m. sternothyroideus
Ansa cervicalis
M. sternocleidomastoideus
mm. scaleni
M. scalenus medius
M. scalenus anterior



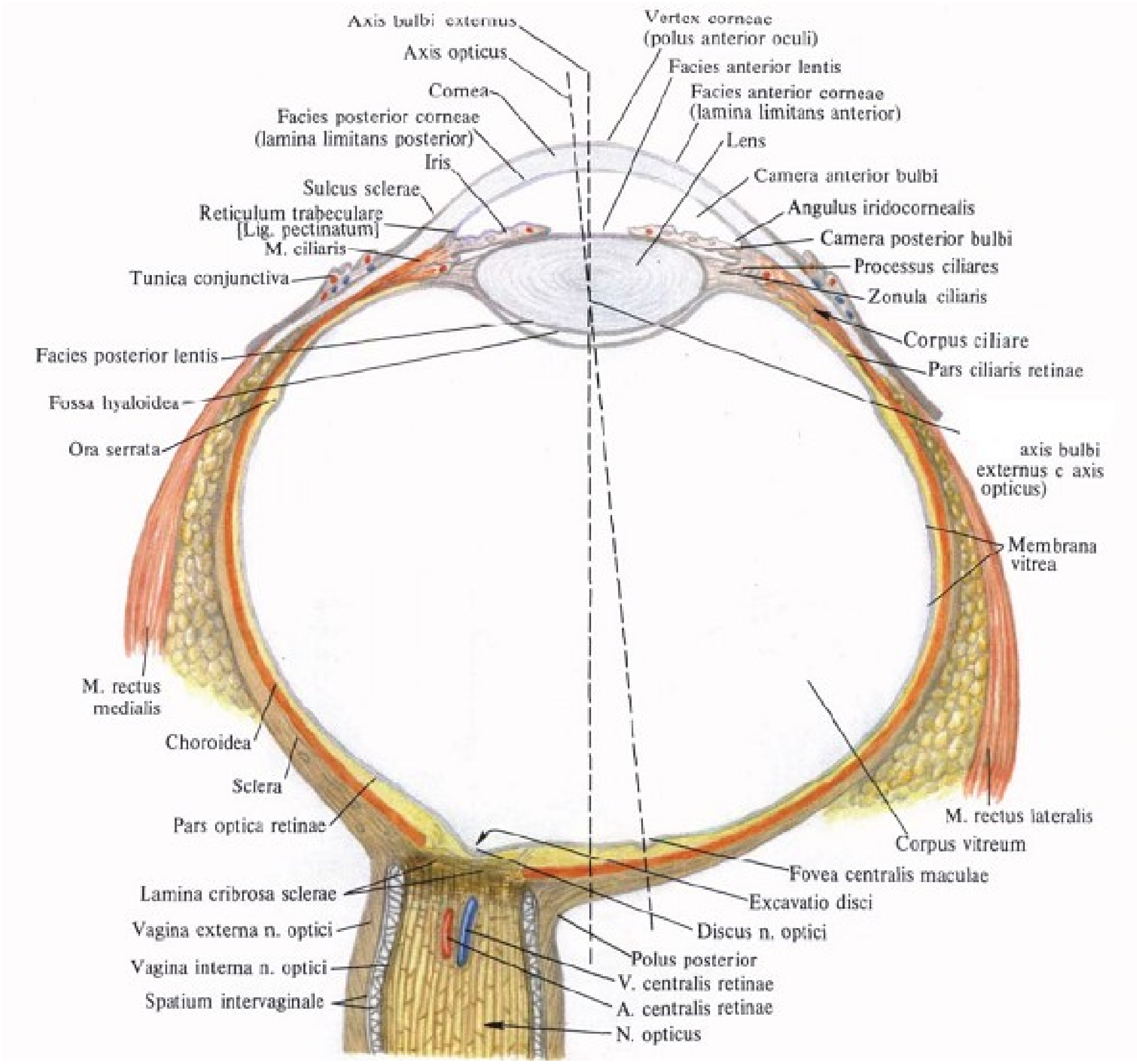
R. muscularis (к m. rectus capitis anterior)
N. hypoglossus
N. occipitalis minor
N. auricularis magnus
Rr. communicantes
N. transversus colli
R. muscularis (к m. geniohyoideus)
R. muscularis (к m. thyrohyoideus)
Radix superior
Radix inferior
R. muscularis (к m. trapezius)
Ansa cervicalis
Nn. supraclaviculares
C_I
C_{II}
C_{III}
C_{IV}
C_V
C_{VI}
C_{VII}
Rr. musculares (к m. longus capitis, m. longus colli et mm. intertransversarii)
Ganglion cervicale superius
Truncus sympathicus
Ganglion cervicale medium
A. vertebralis
N. phrenicus
Rr. musculares (к m. sternothyroideus, m. omohyoideus et m. sternohyoideus)



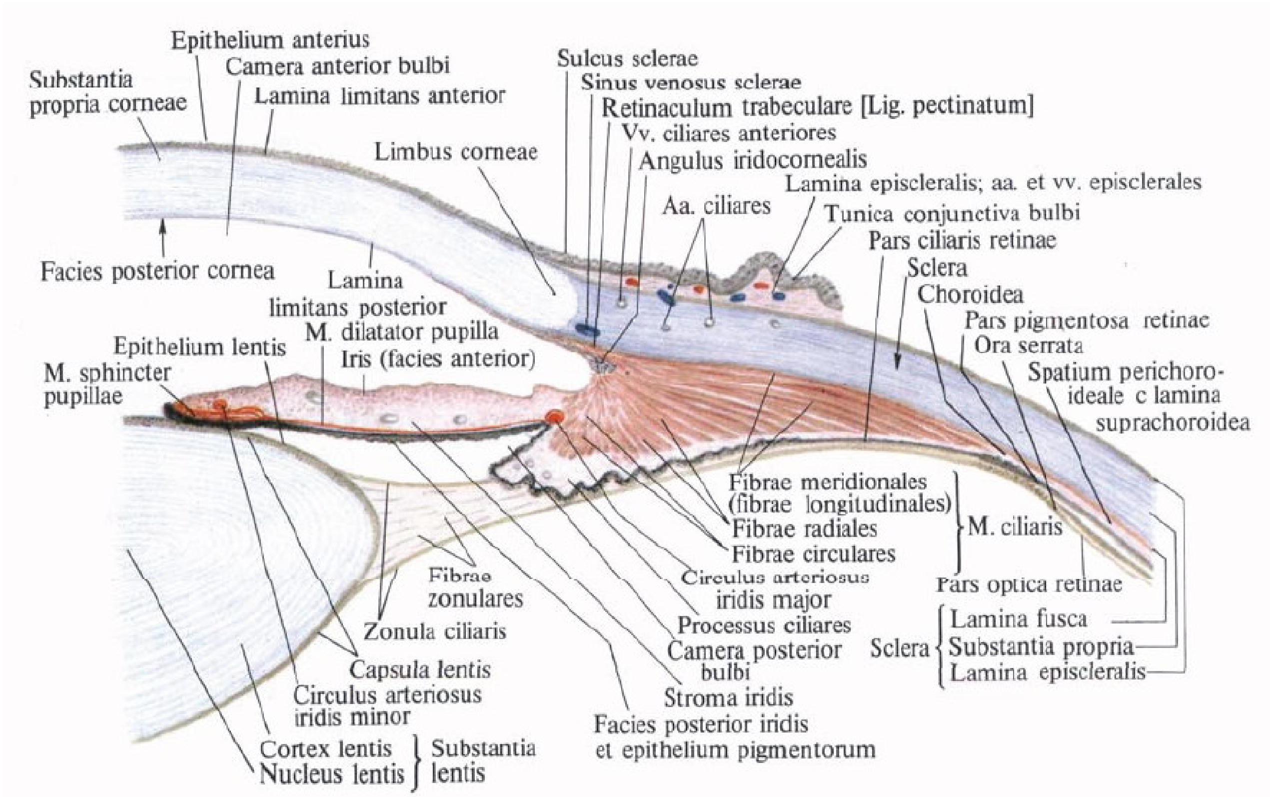
M. sternocleidomastoideus
N. auricularis magnus (rami anteriores et postesriores)
Platysma
V. auricularis posterior
N. occipitalis major
A. occipitalis
V. occipitalis
Ramus marginalis mandibulae (n. facialis)
V. retromandibularis
N. occipitalis minor
N. auricularis magnus
R. superior
R. inferior
N. transversus colli
N. transversus colli
Lamina superficialis fasciae cervicalis
N. accessorius
M. trapezius
V. jugularis externa
V. jugularis anterior
Nn. supraclavicularis laterales (posteriores)
Platysma
Nn. supraclaviculares intermedii
Nn. supraclaviculares mediales



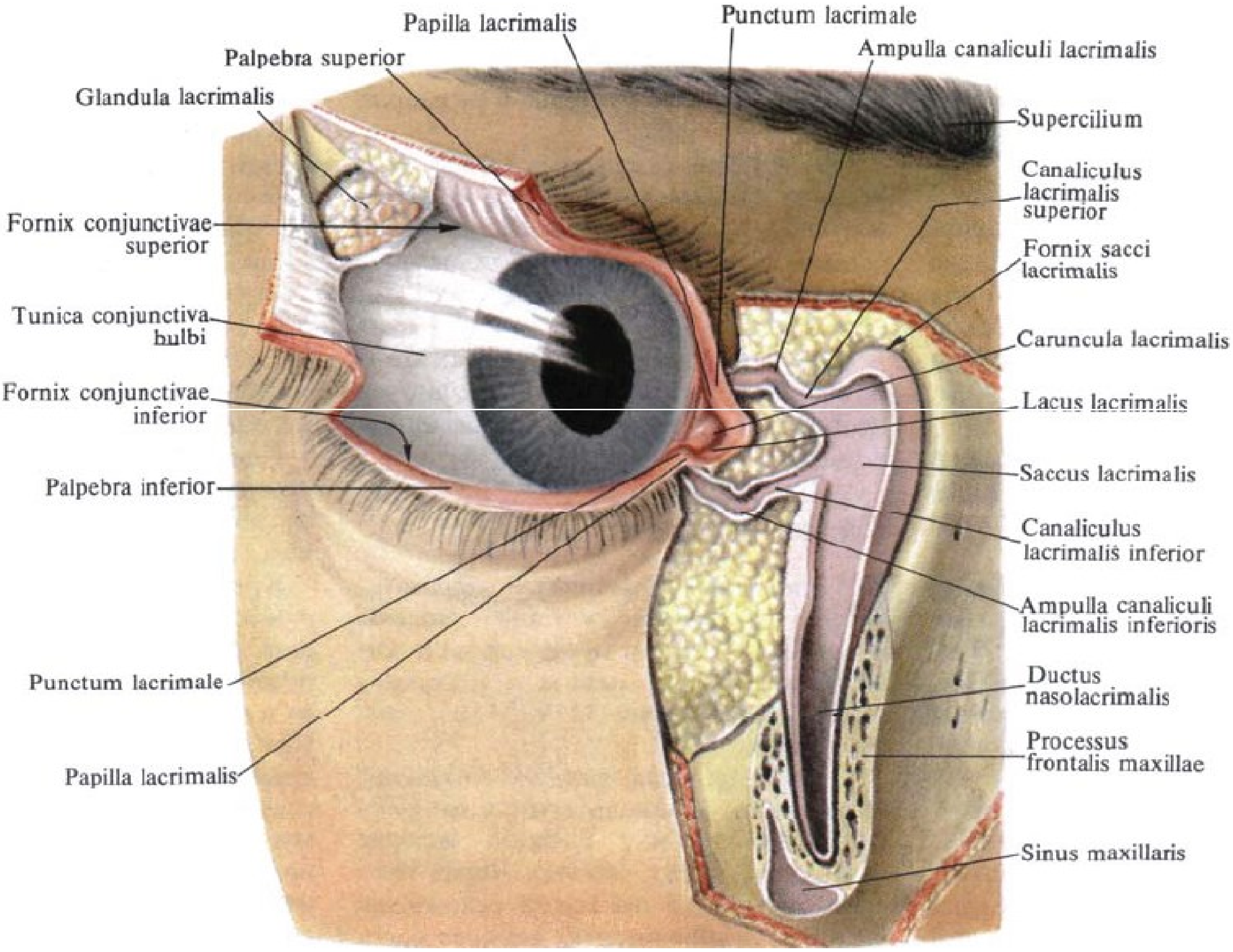
N. nasociliaris
N. maxillaris
N. ophtalmicus
A. ophtalmica
N. opticus
N. oculomotorius
N. canalis pterygoidei (radix facialis)
N. petrosus major
N. petrosus profundus
R. tentorii
N. trigeminus
N. mandibularis
R. meningeus n. mandibularis
R. communicans cum r. meningeo (от n. mandibularis)
Ganglion geniculi
Ganglion oticum
N. tensoris tympani
N. petrosus minor
Radix sympathicus
Chorda tympani
R. communicans cum n. auriculotemporalis
A. meningea media
R. communicans cum chorda tympani
Ganglion rostralis
A. temporalis superficialis
N. facialis
Ganglion caudalis
N. auriculotemporalis
N. glossopharyngeus
Glandula parotis
Ganglion cervicale superior
A. carotis interna
A. carotis externa
A. carotis communis
A. facialis
Глоточная ветвь
R. sympathicus
Rr. glandulares
Glandula submandibularis
Ganglion submandibulare
Rr. ganglionares
Glandula sublingualis
Ganglion sublinguale
N. nasopalatinus
Nn. palatini major et minor
N. lingualis
N. pterygoideus medialis
N. buccalis
A. maxillaris
Rr. nasalis posteriores superic от ganglion pterygopalatinum
N. tensoris veli palatini
N. pterygoideus lateralis
Ganglion pterygopalatinum
Rr. orbitales ganglion pterygopalatinum
Rr. ganglionares n. maxillari
N. zygomaticus
R. communicans cum n. zygomatico
Glandula lacrimalis
Ganglion ciliare
N. lacrimalis (n. intermediofacialis)
N. supraorbitalis
Radix oculomotoria
Radix sympathicus
Radix nasociliaris



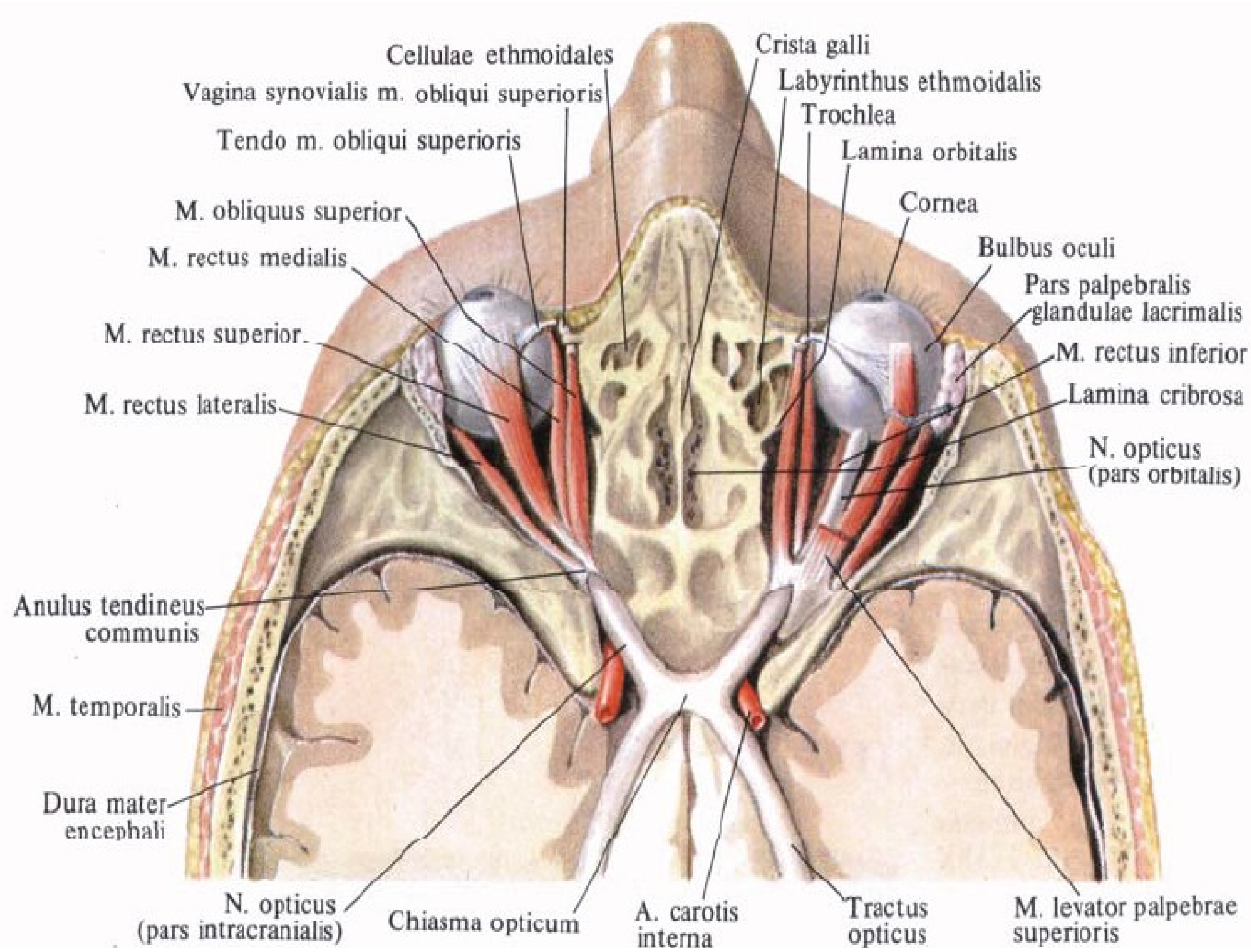
Axis bulbi externus
Axis opticus
Cornea
Facies posterior corneae
(lamina limitans posterior)
Iris
Sulcus sclerae
Reticulum trabeculare
[Lig. pectinatum]
M. ciliaris
Tunica conjunctiva
Facies posterior lentis
Fossa hyaloidea
Ora serrata
M. rectus
medialis
Choroidea
Sclera
Pars optica retinae
Lamina cribrosa sclerae
Vagina externa n. optici
Vagina interna n. optici
Spatium intervaginale
Vertex corneae
(polus anterior oculi)
Facies anterior lentis
Facies anterior corneae
(lamina limitans anterior)
Lens
Camera anterior bulbi
Angulus iridocornealis
Camera posterior bulbi
Processus ciliares
Zonula ciliaris
Corpus ciliare
Pars ciliaris retinae
axis bulbi
externus c axis
opticus)
Membrana
vitrea
M. rectus lateralis
Corpus vitreum
Fovea centralis maculae
Excavatio disci
Discus n. optici
Polus posterior
V. centralis retinae
A. centralis retinae
N. opticus



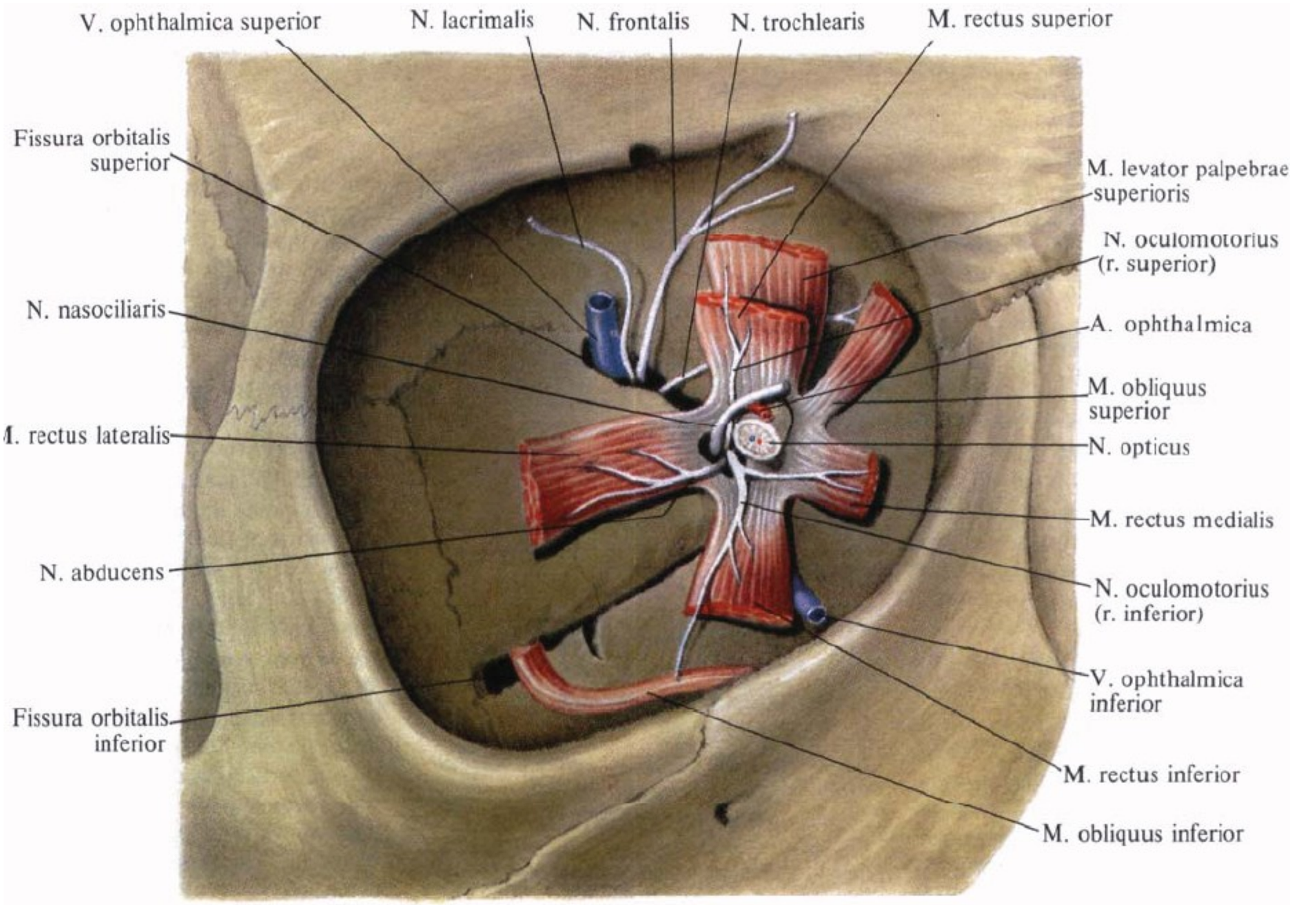
Epithelium anterius
Camera anterior bulbi
Substantia propria corneae
Lamina limitans anterior
Limbus corneae
Facies posterior cornea
Lamina limitans posterior
M. dilatator pupilla
Epithelium lentis
Iris (facies anterior)
M. sphincter pupillae
Sulcus sclerae
Sinus venosus sclerae
Retinaculum trabeculare [Lig. pectinatum]
Vv. ciliares anteriores
Angulus iridocornealis
Lamina episcleralis; aa. et vv. episclerales
Aa. ciliares
Tunica conjunctiva bulbi
Pars ciliaris retinae
Sclera
Choroidea
Pars pigmentosa retinae
Ora serrata
Spatium perichoroideale c lamina suprachoroidea
Fibrae meridionales (fibrae longitudinales)
Fibrae radiales
Fibrae circulares
M. ciliaris
Circulus arteriosus iridis major
Pars optica retinae
Fibrae zonulares
Zonula ciliaris
Processus ciliares
Camera posterior bulbi
Capsula lentis
Circulus arteriosus iridis minor
Stroma iridis
Sclera
Lamina fusca
Substantia propria
Lamina episcleralis
Facies posterior iridis et epithelium pigmentorum
Cortex lentis
Nucleus lentis
Substantia lentis

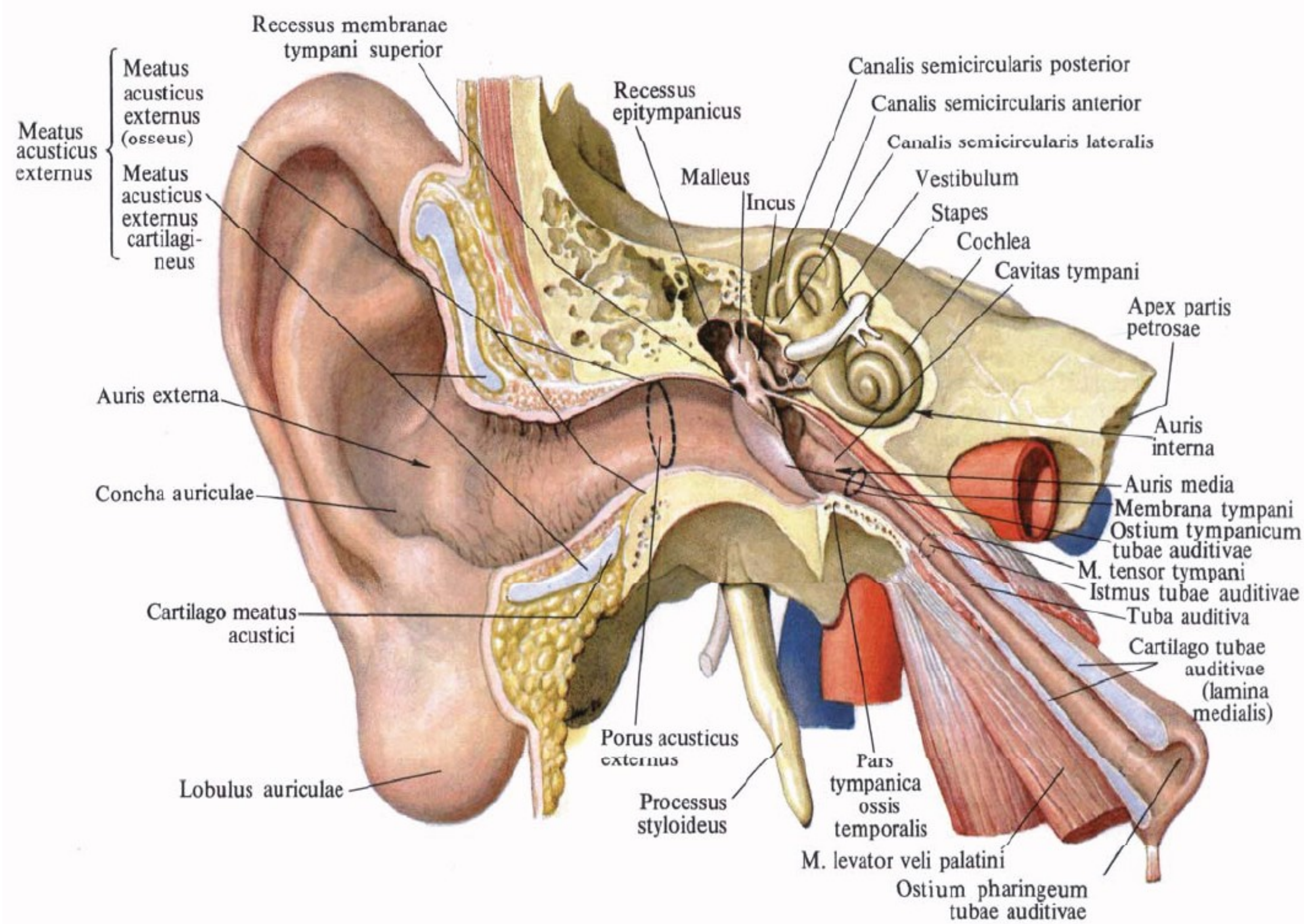


Papilla lacrimalis
Punctum lacrimale
Ampulla canaliculi lacrimalis
Palpebra superior
Glandula lacrimalis
Supercilium
Canaliculus lacrimalis superior
Fornix conjunctivae superior
Fornix sacci lacrimalis
Tunica conjunctiva bulbi
Caruncula lacrimalis
Fornix conjunctivae inferior
Lacus lacrimalis
Saccus lacrimalis
Palpebra inferior
Canaliculus lacrimalis inferior
Ampulla canaliculi lacrimalis inferioris
Punctum lacrimale
Ductus nasolacrimalis
Processus frontalis maxillae
Papilla lacrimalis
Sinus maxillaris

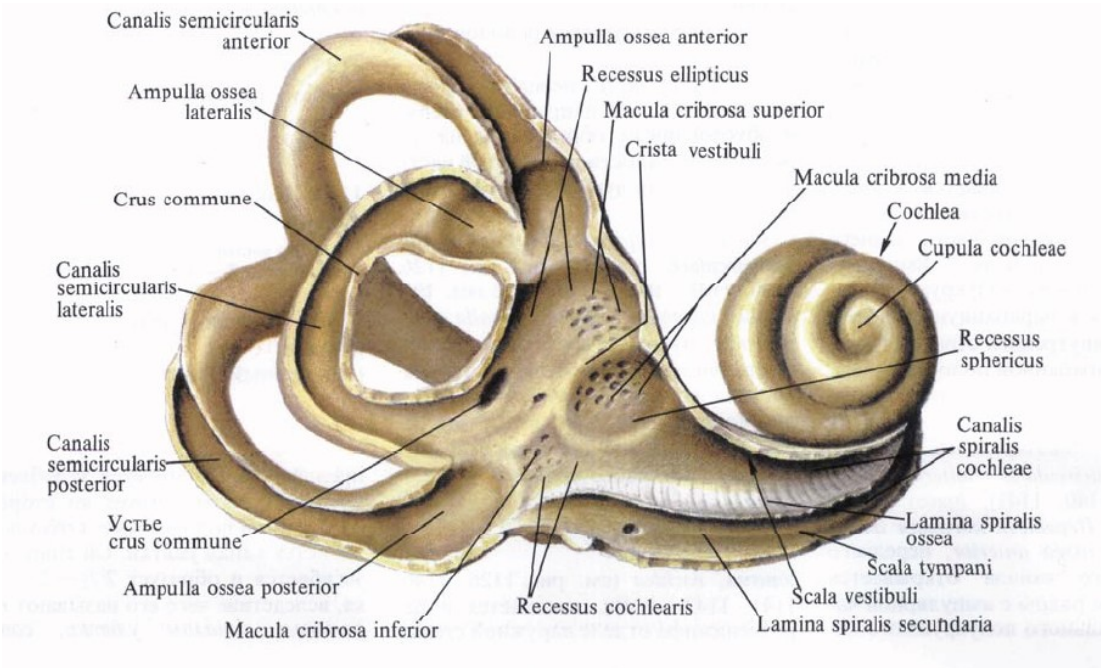


Cellulae ethmoidales
Vagina synovialis m. obliqui superioris
Tendo m. obliqui superioris
M. obliquus superior
M. rectus medialis
M. rectus superior
M. rectus lateralis
Anulus tendineus communis
M. temporalis
Dura mater encephali
N. opticus (pars intracranialis)
Chiasma opticum
A. carotis interna
Tractus opticus
M. levator palpebrae superioris
Crista galli
Labyrinthus ethmoidalis
Trochlea
Lamina orbitalis
Cornea
Bulbus oculi
Pars palpebralis glandulae lacrimalis
M. rectus inferior
Lamina cribrosa
N. opticus (pars orbitalis)

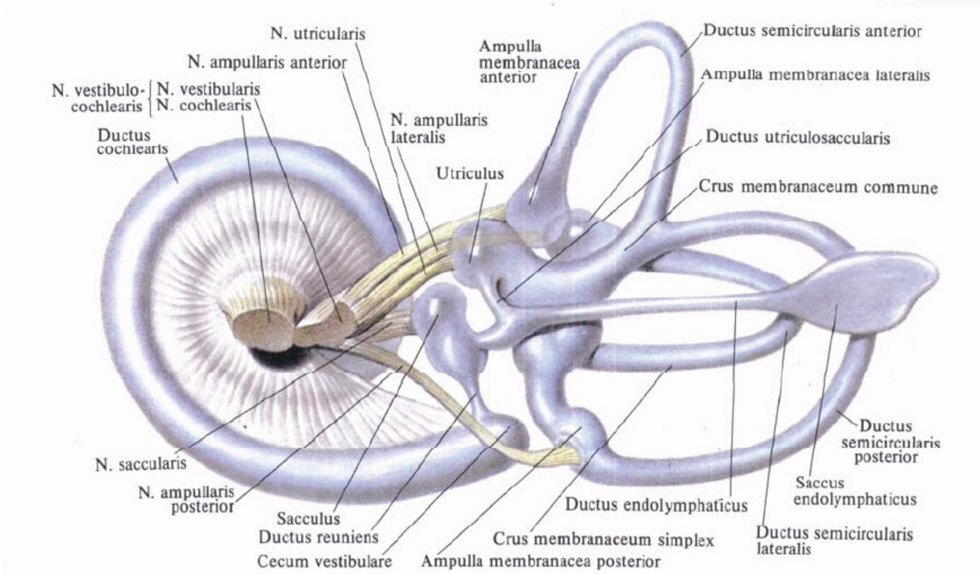

V. ophthalmica superior
N. lacrimalis
N. frontalis
N. trochlearis
M. rectus superior
Fissura orbitalis superior
M. levator palpebrae superioris
N. oculomotorius (r. superior)
N. nasociliaris
A. ophthalmica
M. obliquus superior
M. rectus lateralis
N. opticus
M. rectus medialis
N. abducens
N. oculomotorius (r. inferior)
V. ophthalmica inferior
Fissura orbitalis inferior
M. rectus inferior
M. obliquus inferior



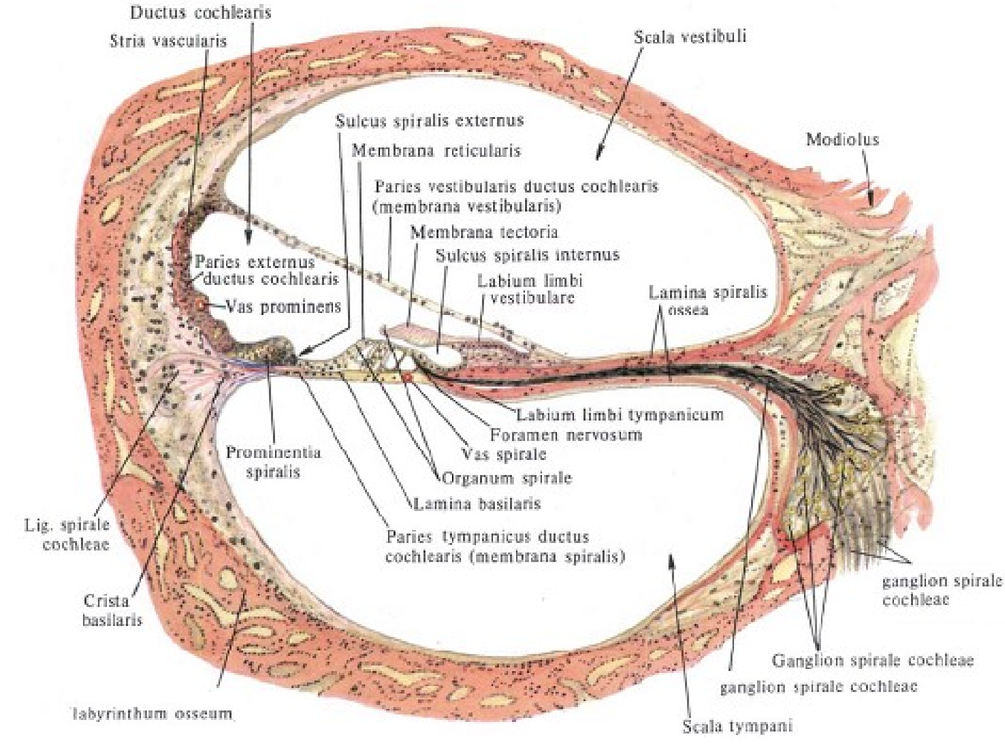
Recessus membranae tympani superior
Meatus acusticus externus
Meatus acusticus externus (osseus)
Meatus acusticus externus cartilagineus
Recessus epitympanicus
Malleus
Incus
Canalis semicircularis posterior
Canalis semicircularis anterior
Canalis semicircularis lateralis
Vestibulum
Stapes
Cochlea
Cavitas tympani
Apex partis petrosae
Auris interna
Auris externa
Concha auriculae
Auris media
Membrana tympani
Ostium tympanicum tubae auditivae
M. tensor tympani
Istmus tubae auditivae
Tuba auditiva
Cartilago tubae auditivae (lamina medialis)
Cartilago meatus acustici
Porus acusticus externus
Pars tympanica ossis temporalis
Lobulus auriculae
Processus styloideus
M. levator veli palatini
Ostium pharingeum tubae auditivae



Canalis semicircularis anterior
Ampulla ossea anterior
Recessus ellipticus
Ampulla ossea lateralis
Macula cribrosa superior
Crista vestibuli
Macula cribrosa media
Crus commune
Cochlea
Cupula cochleae
Canalis semicircularis lateralis
Recessus sphericus
Canalis spiralis cochleae
Canalis semicircularis posterior
Lamina spiralis ossea
Устье crus commune
Scala tympani
Ampulla ossea posterior
Scala vestibuli
Recessus cochlearis
Lamina spiralis secundaria
Macula cribrosa inferior

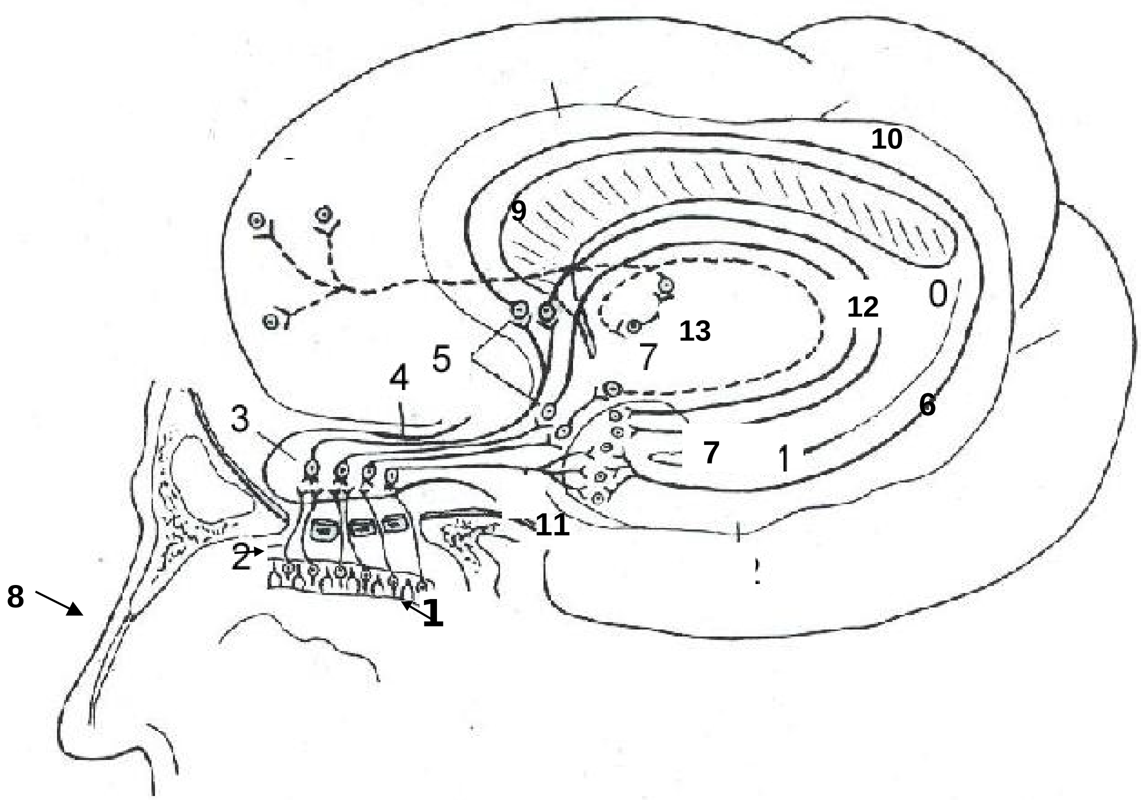


N. utricularis
Ductus semicircularis anterior
Ampulla membranacea anterior
N. ampullaris anterior
Ampulla membranacea lateralis
N. vestibulo-cochlearis
N. vestibularis
N. cochlearis
N. ampullaris lateralis
Ductus utriculosaccularis
Ductus cochlearis
Utriculus
Crus membranaceum commune
Ductus semicircularis posterior
Saccus endolymphaticus
N. saccularis
N. ampullaris posterior
Ductus endolymphaticus
Sacculus
Ductus reuniens
Ductus semicircularis lateralis
Crus membranaceum simplex
Cecum vestibulare
Ampulla membranacea posterior



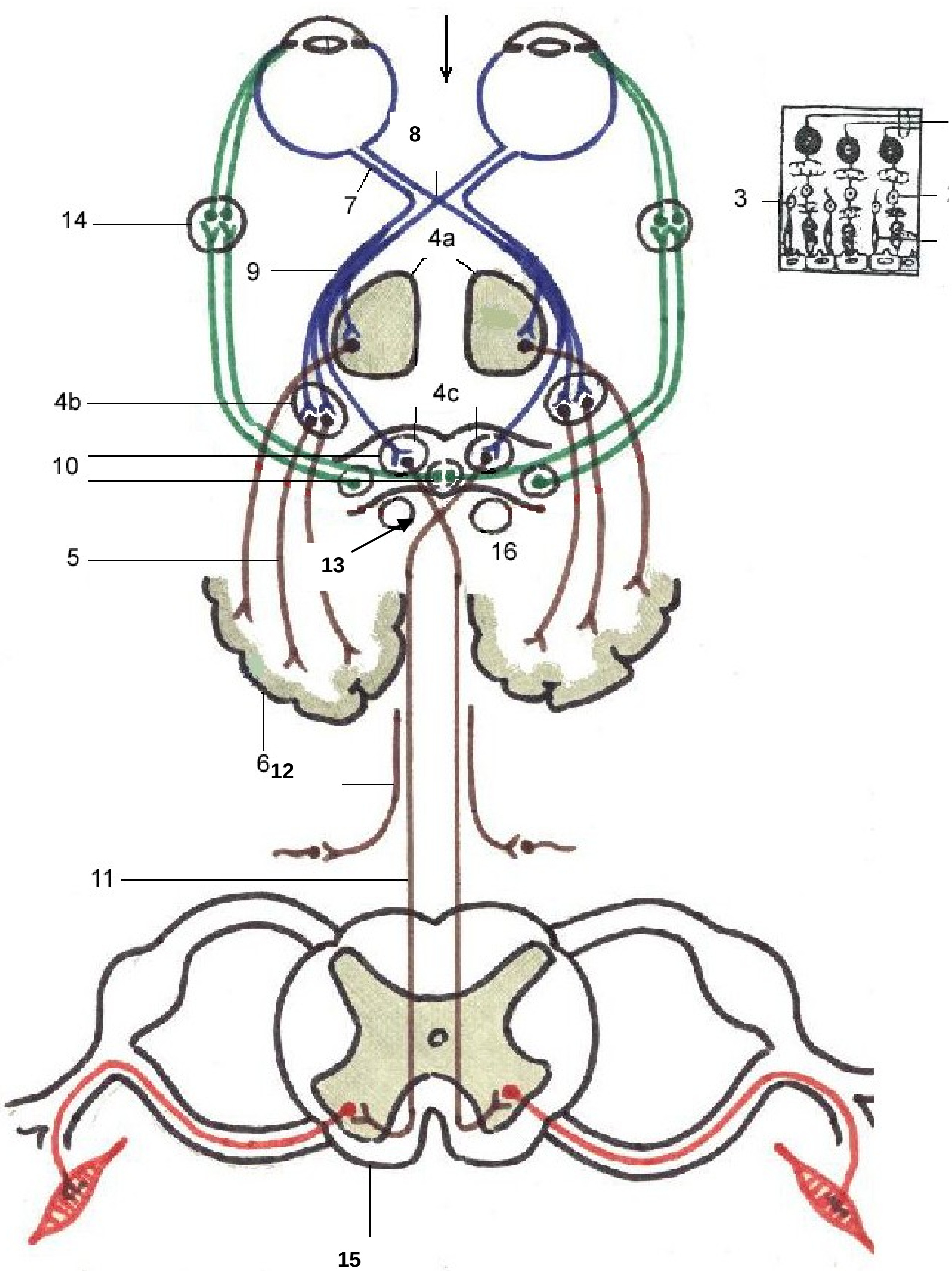
Ductus cochlearis
Stria vascularis
Scala vestibuli
Sulcus spiralis externus
Membrana reticularis
Modiolus
Paries vestibularis ductus cochlearis (membrana vestibularis)
Membrana tectoria
Sulcus spiralis internus
Paries externus ductus cochlearis
Labium limbi vestibulare
Vas prominens
Lamina spiralis ossea
Labium limbi tympanicum
Foramen nervosum
Vas spirale
Prominentia spiralis
Organum spirale
Lamina basilaris
Lig. spirale cochleae
Paries tympanicus ductus cochlearis (membrana spiralis)
ganglion spirale cochleae
Crista basilaris
Ganglion spirale cochleae
ganglion spirale cochleae
labyrinthum osseum
Scala tympani

Conducting pathways of the olfactory analyzer



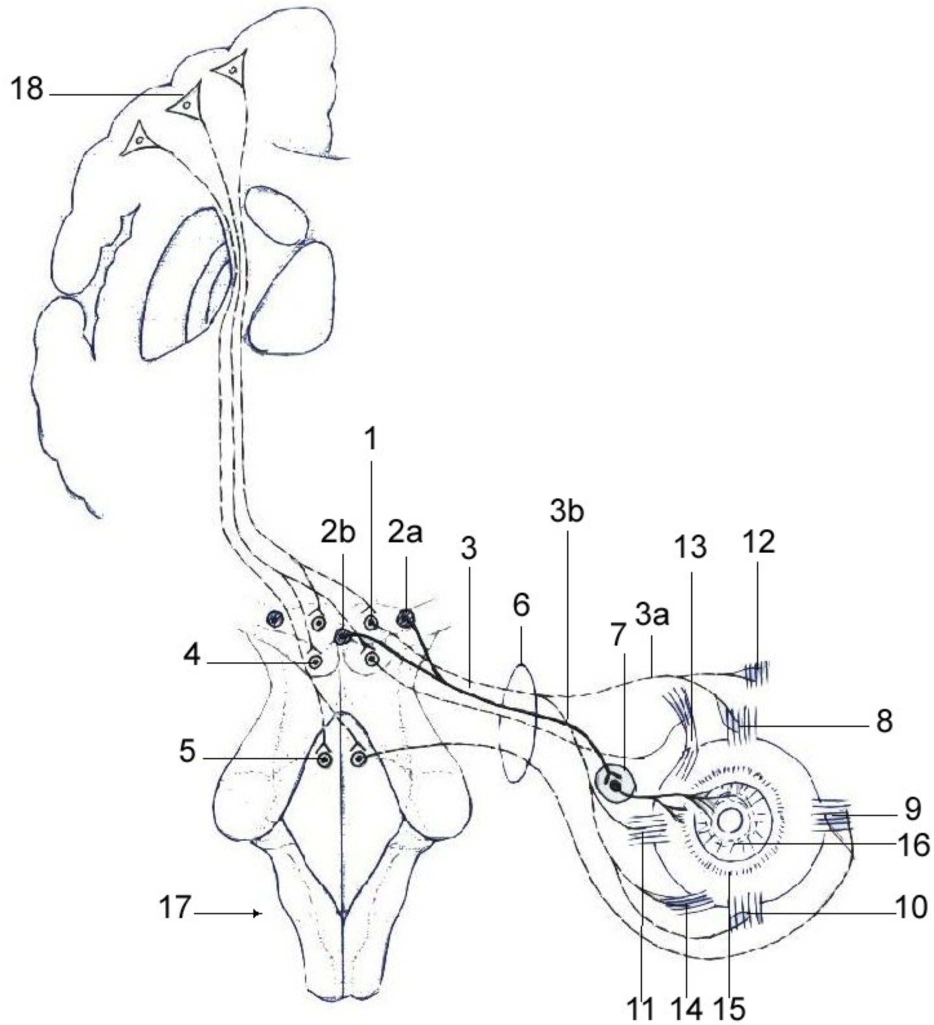
1 – neuronum I (cellulae bipolares neurosensoriales);
2 – filae olfactoriae;
3 – neuronum II (cellulae mitrales bulbi olfactorii);
4 – tractus olfactorius;
5 – neuronum III (trigonum olfactorium, substantia perforata anterior, septum pellucidum);
6 – gyrus parahyppocampalis;
7 – uncus, corpus amygdaloideum et area subcallosa;
8 – nasus externus;
9 – corpus callosum;
10 – gyrus cinguli;
11– gyrus dentatus;
12– fornix;
13– thalamus.

Conducting pathways of the optic analyzer



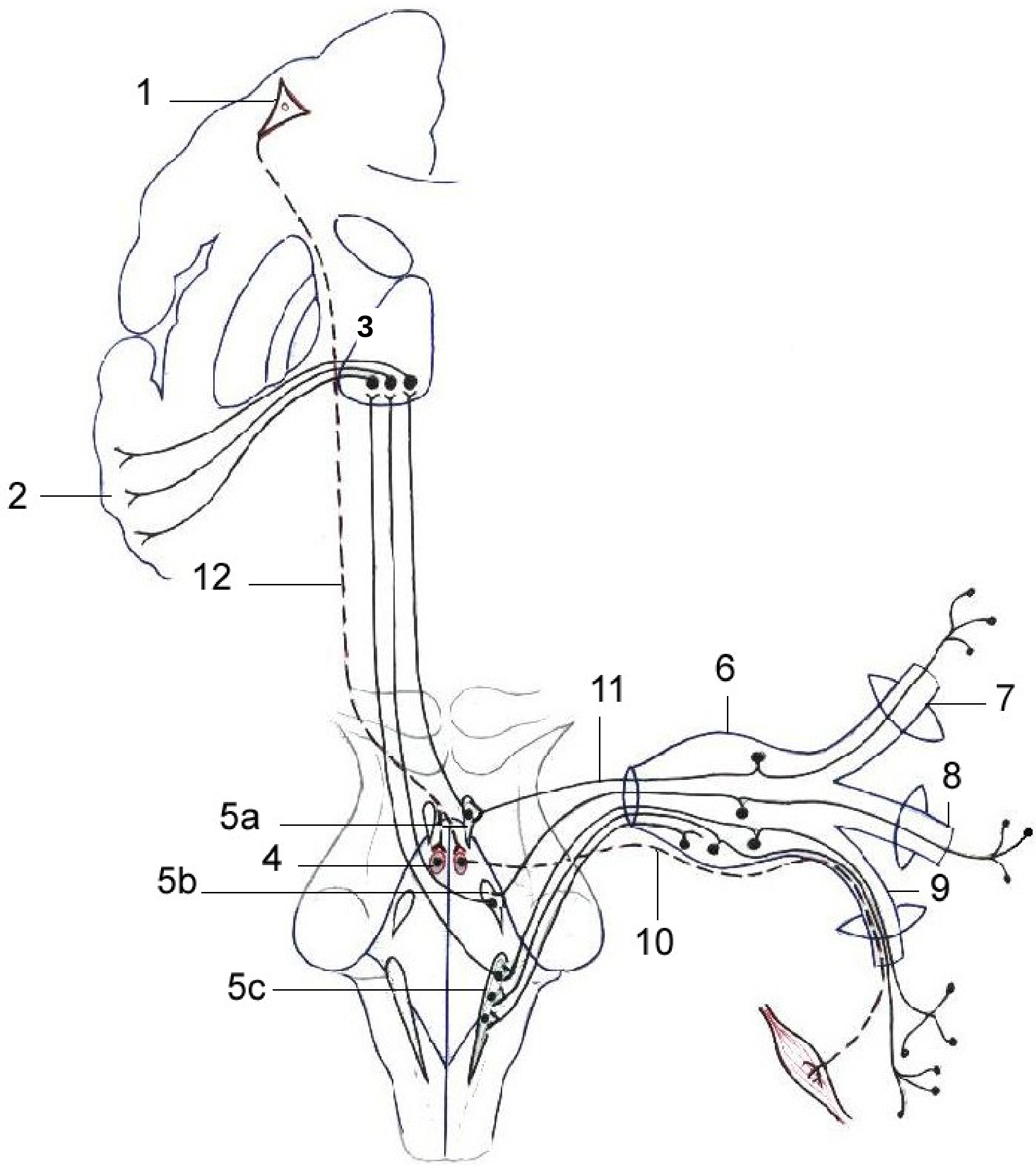
1 – epitheliocyti (neurosensorii) coniferi et bacilliferi;
2 – neuronum I (neuron bipolare);
3 – neuronum II (neuron ganglionare multipolare);
4 – neuronum III:
4a – pulvinar thalami;
4b – corpus geniculatum laterale;
4c – colliculi superiores;
5 – radiatio optica (Gratiolet);
6 – regio sulci calcarini;
7 – nervus opticus;
8 – chiasma optica;
9 – tractus opticus;
10 – nuclei n. oculomotorii;
11 – tractus tectospinalis;
12 – tractus tectobulbaris;
13 – decussatio dorsalis tegmenti (Meynert);
14 – ganglion ciliare;
15 – medulla spinalis;
16 – colliculi inferiores.

Innervation of the muscles of the eyeball



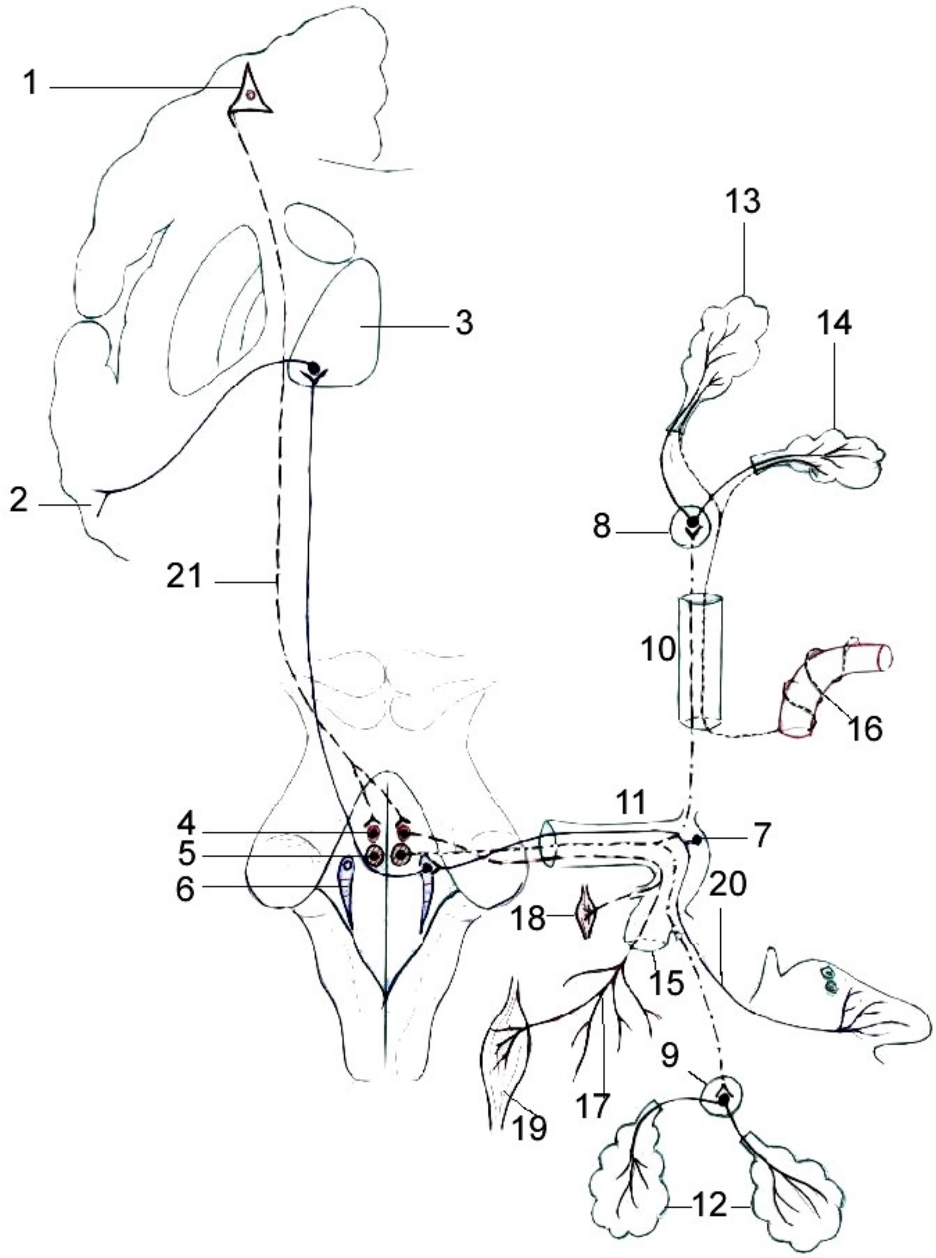
1 – nucl. n. oculomotorii (III);
2a – n. accessorius (Якубович-Edinger-Westfal);
2b – nucleus impar (Perl) (III);
3 – nervus oculomotorius:
3a – ramus superior;
3b – ramus inferior;
4 – nucl.n. trochlearis (IV);
5 – nucl.n. abducentis(VI);
6 – fissura orbitalis superior;
7 – ganglion ciliare;
8 – m. rectus superior;
9 – m. rectus lateralis;
10 – m. rectus inferior;
11 – m. rectus medialis;
12 – m. levator palpebrae superioris;
13 – m. obliquus superior;
14 – m. obliquus inferior;
15 – m. ciliaris;
16 – m. sphincter pupillae;
17 – truncus cerebri;
18 – neurocytus pyramidalis magnus (Betz).

Conducting pathways of the trigeminal nerve (V)



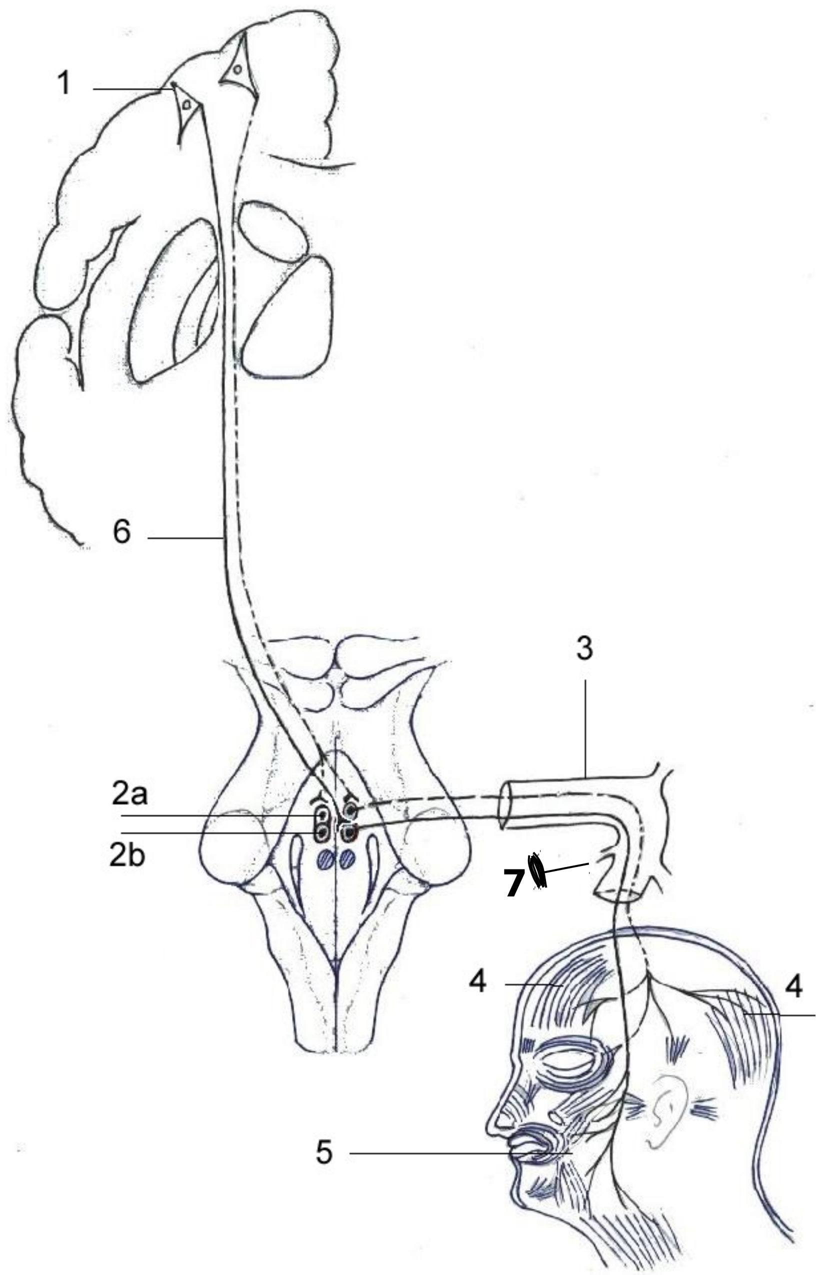
1 – neuronum I (neurocytus pyramidalis magnus, Betz) (gyrus precentralis);
2 – gyrus postcentralis;
3 – neuronum III (thalamus opticus):
4 – nucl. n. trigemini (V);
5 – nuclei sensoriales n. trigemini (V);
5a – nucl. mesencephalicus n. trigemini (V);
5b – nucl. pontinus (V);
5c – nucl. spinalis nervi trigemini (V);
6 – ganglion trigeminale (Gasser);
7 – n. ophthalmicus;
8 – n. maxillaris;
9 – n. mandibularis;
10 – radix motoria n. trigemini;
11 – radix sensoria n. trigemeni;
12 – tractus corticonuclearis.

Conducting pathways of the facial nerve (VII)



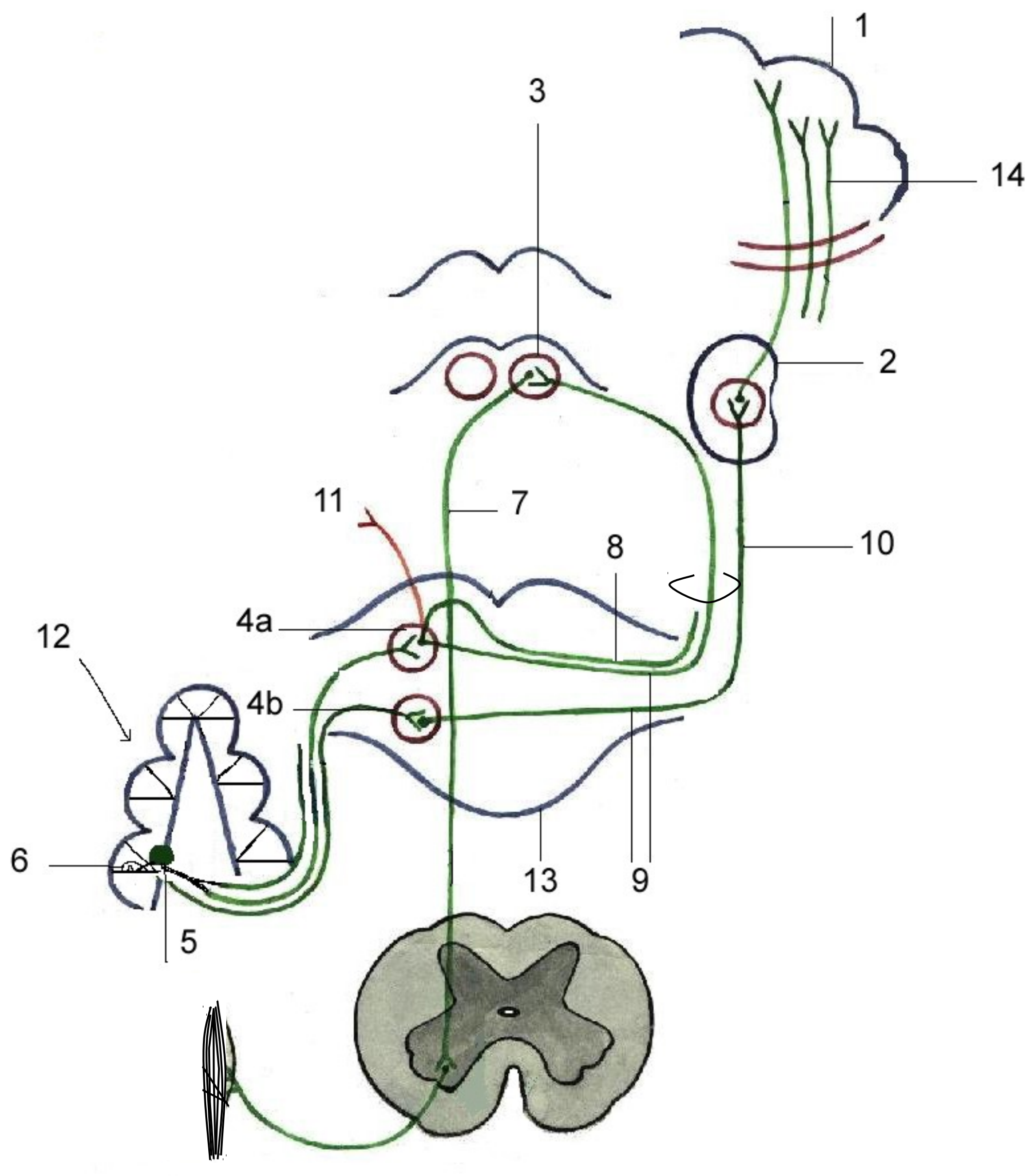
1 – neuronum I (neurocytus pyramidalis magnus, Betz) (gyrus precentralis);
2 – girus parahipocampalis et uncus;
3 – thalamus opticus;
4 – nucl. n. facialis (motorius) (neuronum II) (VII);
5 – n. salivatorius superior (VII);
6 – n. tractus solitarii (VII);
7 – ganglion geniculi;
8 – ganglion pterygopalatinum;
9 – ganglia submandibularia et sublingualia;
10 – canalis pterygoideus;
11 – canalis n. facialis (Fallopius);
12 – glandulae sublingualis et submandibularis;
13 – glandula lacrimalis;
14 – glandulae nasales;
15 – foramen stylomastoideum;
16 – plexus caroticus internus;
17 – plexus parotideus;
18 – m. stapedius;
19 – mm. faciei;
20 – chorda tympani;
21 – tractus corticonuclearis.

Efferent, motor pathways of the facial nerve (VII)



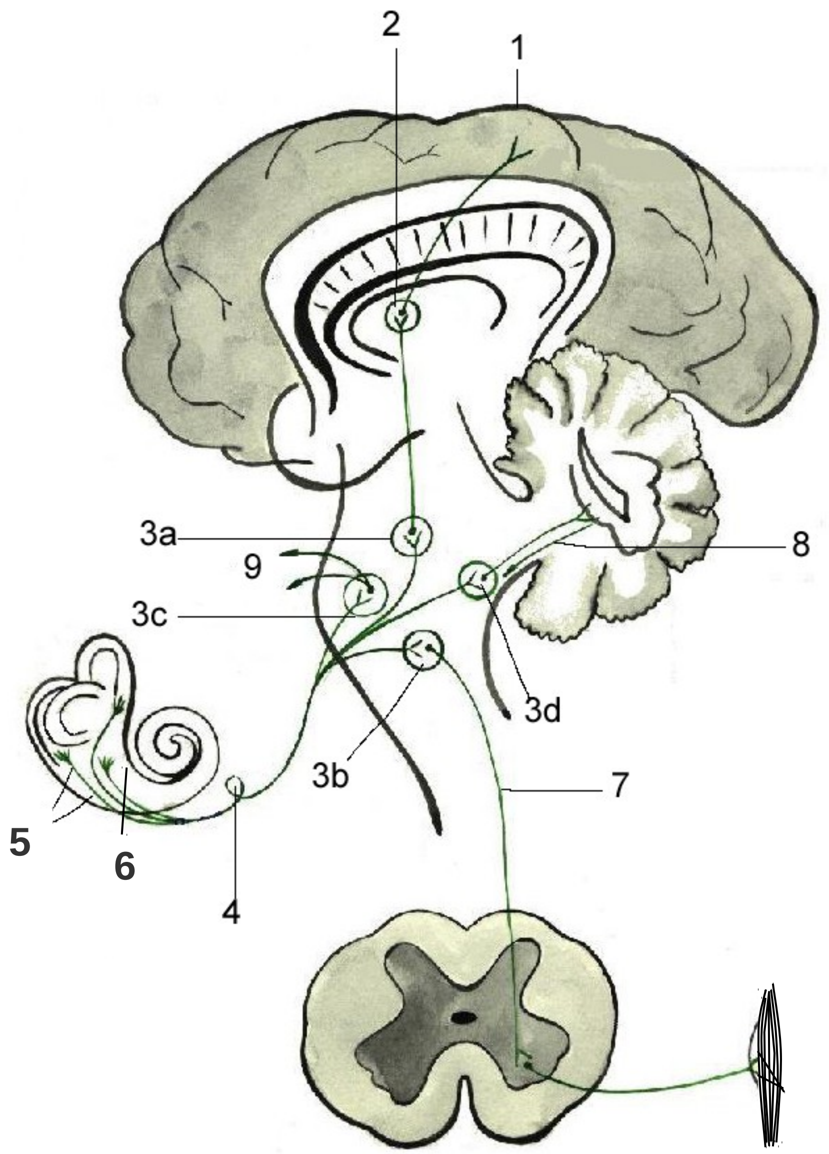
1 – neuronum I (neurocytus pyramidalis magnus, Betz) (girus precentralis);
2 – neuronum II (nucl. n. facialis, motorius) (VII);
2a – pars superior;
2b – pars inferior;
3 – canalis n. facialis;
4 – mm. faciei superiores;
5 – mm. faciei inferiores;
6 – tractus corticonuclearis;
7 – m. stapedius.

Conducting pathways of the auditory analyzer



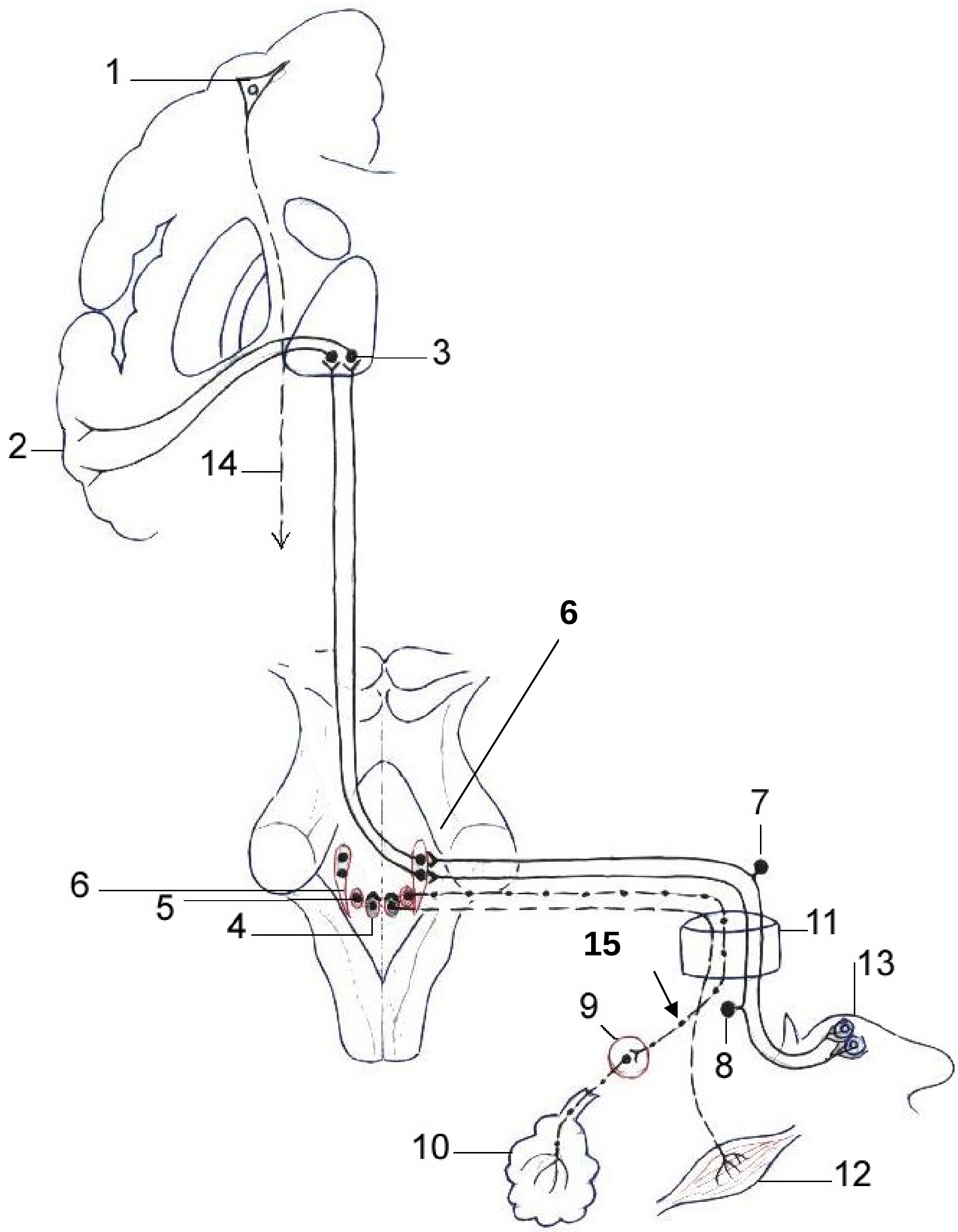
1 – gyri temporales transversi (Heschl) (gyrus temporalis superior);
2 – neuronum III (corpus geniculatum mediale);
3 – neuronum III (colliculus inferior tecti mesencephali);
4 – neuronum II (nuclei partes cochlearis n. vestibulocochlearis);
4a – nucleus dorsalis;
4b – nucleus ventralis;
5 – neuronum I [ganglion spirale (Corti)];
6 – organum Corti (epitheliocytus neurosensorius);
7 – tractus tectospinalis;
8 – striae medullares;
9 – corpus trapezoideum;
10 – lemniscus lateralis;
11 – conexiones ad nervos III, IV, VI;
12 – cochlea (labyrinthus osseus);
13 – pons Varolio;
14 – radiatio acustica.

Conducting pathways of the vestibular analyzer



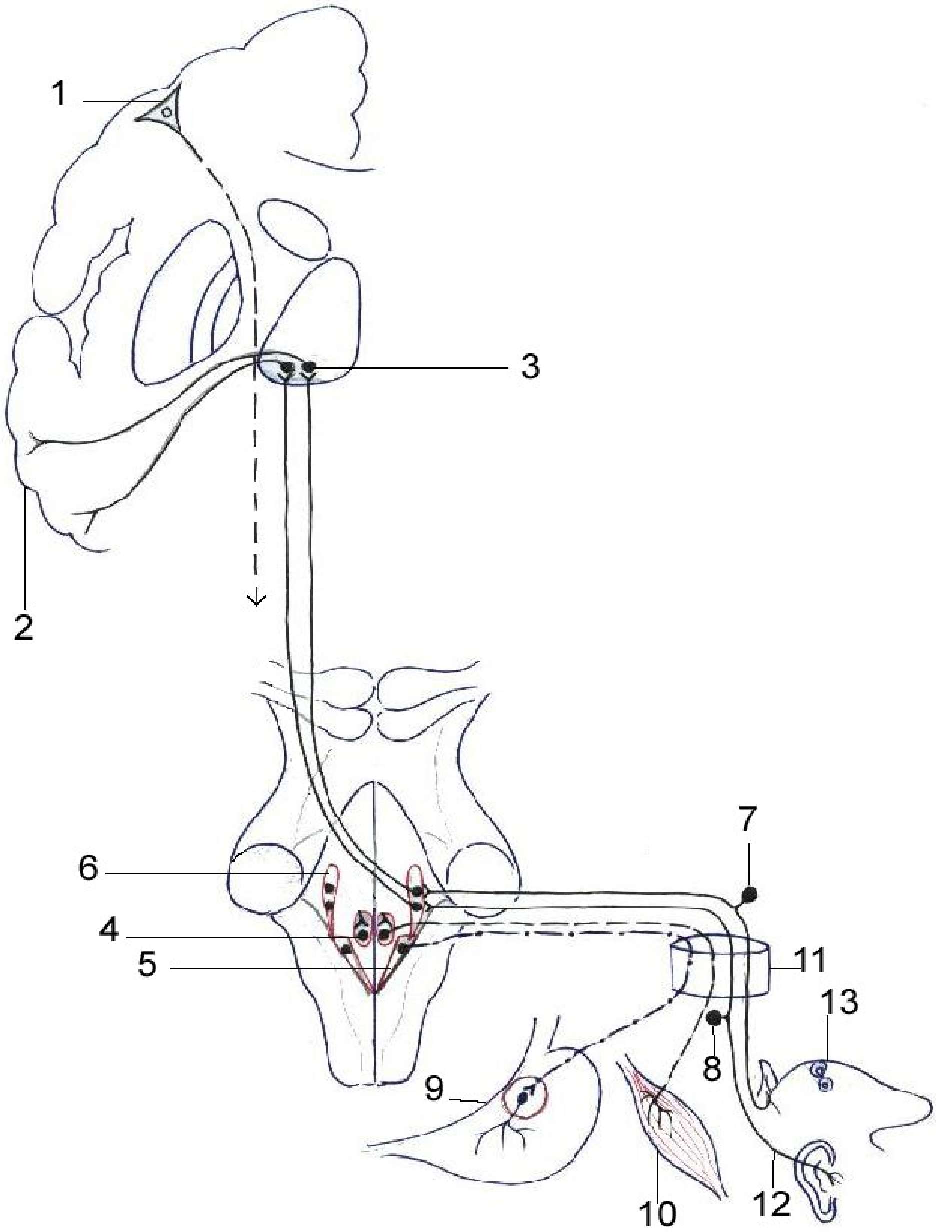
1 – lobus temporalis;
2 – neuronum III (thalamus opticus);
3 – neuronum II (nuclei vestibulares n. vestibulocochlearis):
a – superior (Бехмерев);
b – inferior (Roller);
c – lateralis (Deiters);
d – medialis (Schwalbe);
4 – ganglion vestibulare (Scarpa) (neuronum I);
5 – cristae ampullares ductuum semicircularium;
6 – macula utriculi et macula sacculi;
7 – tractus vestibulospinalis (Levental);
8 – tractus vestibulocerebellaris et tractus cerebellovestibularis;
9 – conexiones ad nervos craniales IX, X et III, IV, VI.

Conducting pathways of the glossopharyngeal nerve (IX)



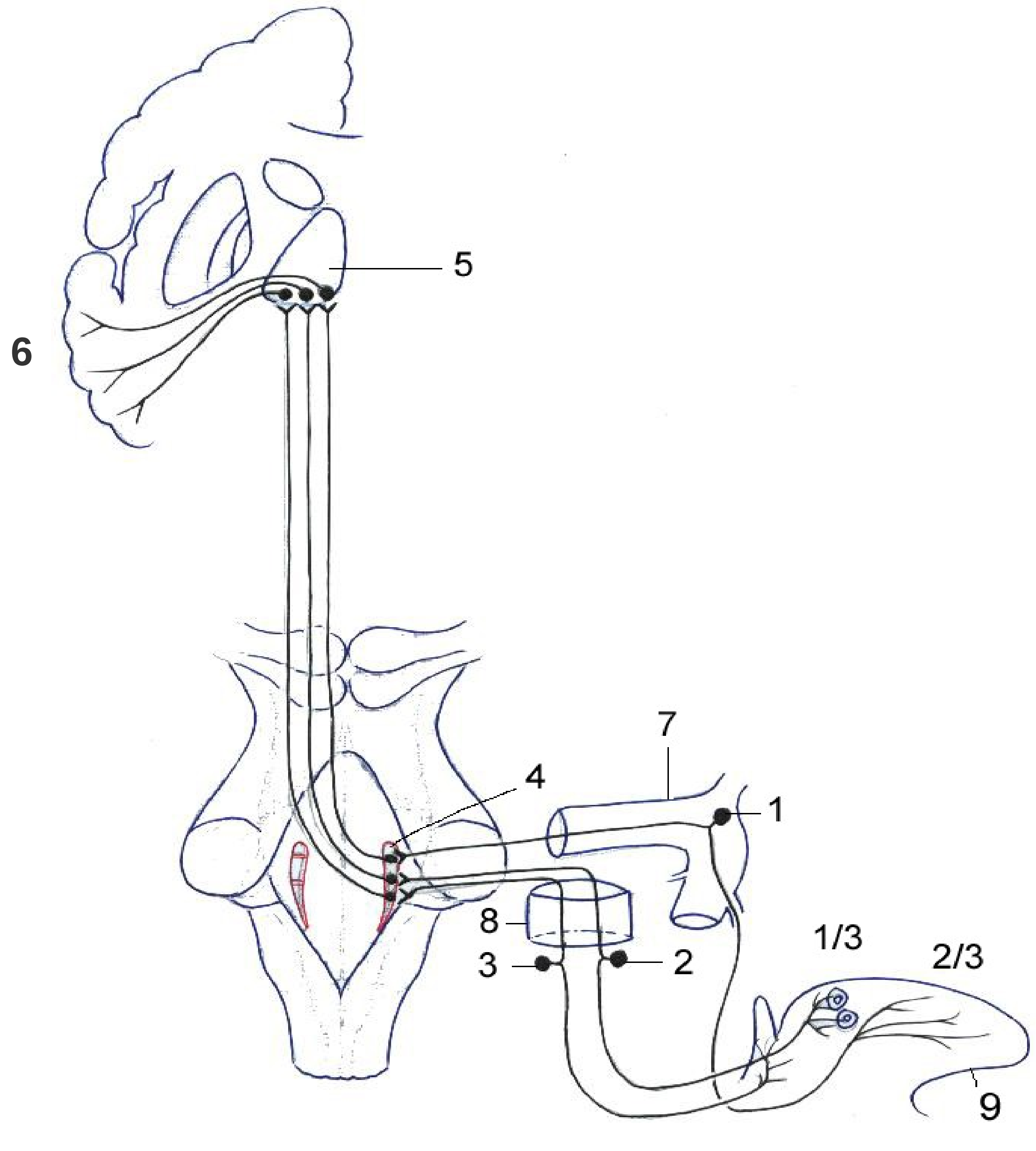
1 – neuronum I (motorium) (gyrus precentralis, neurocytus pyramidalis magnus, Betz);
2 – uncus et gyrus postcentralis;
3 – neuronum III (thalamus opticus);
4 – neuronum II (motorium) (nucleus ambiguus);
5 – nucleus salivatorius inferior (neuronum I);
6 – neuronum II (sensitivum) (nucleus tractus solitarii);
7 – neuronum I (sensitivum) (ganglion superius);
8 – neuronum I (sensitivum) (ganglion inferius, nodosum);
9 – ganglion oticum (neuronum II);
10 – glandula parotis;
11 – foramen jugulare;
12 – ramus musculi stylopharyngei;
13 – 1/3 posterior linguae (papillae valatae);
14 – tractus corticonuclearis;
15 – nervus tympanicus.

Conducting pathways of the vagus nerve (X)



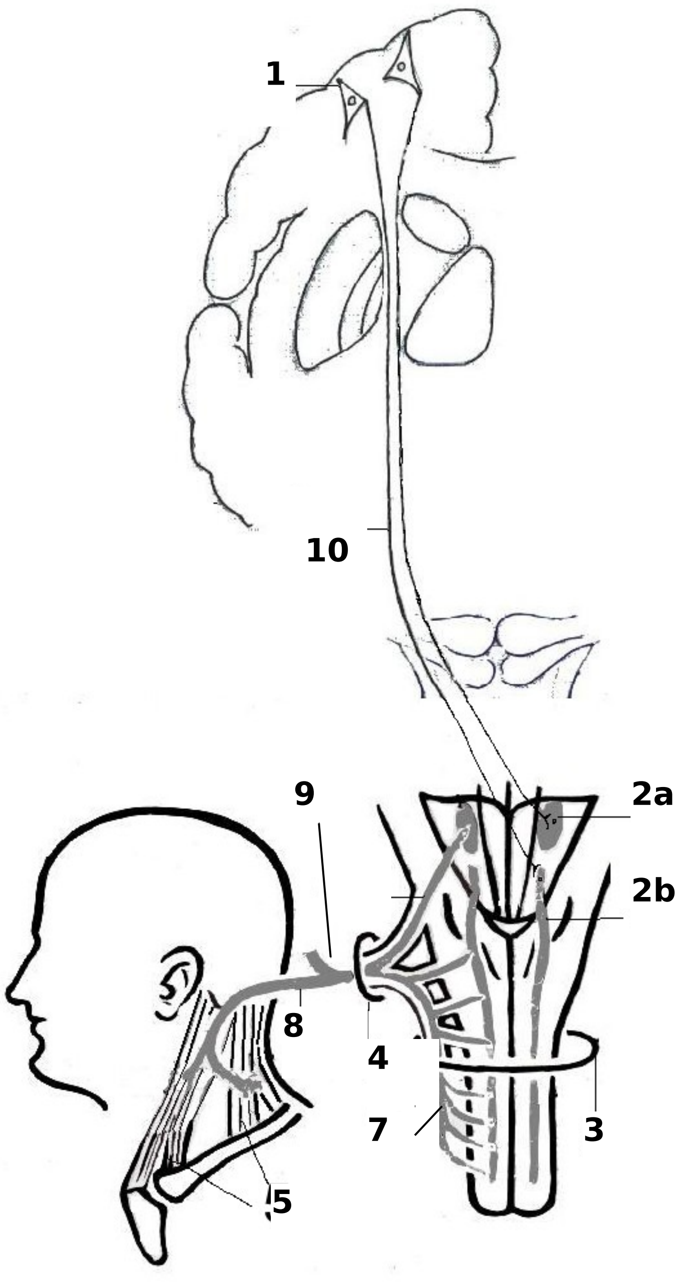
1 – neuronum I (motorium) (gyrus precentralis, neurocytus pyramidalis magnus, Betz);
2 – uncus et gyrus postcentralis;
3 – neuronum III (sensitivum) (thalamus opticus);
4 – neuronum II (motorium) (nucleus ambiguus);
5 – nucleus dorsalis nervi vagi (neuronum I);
6 – neuronum II (sensitivum) (nucleus tractus solitarii);
7 – neuronum I (sensitivum) (ganglion superius, jugulare);
8 – neuronum I (sensitivum) (ganglion inferius, nodosum);
9 – ganglia intraviscerali et paraviscerali (neuronum II);
10 – mm. pharyngis, laryngis, palati mollis etc.;
11 – foramen jugulare;
12 – nervus auricularis posterior;
13 – radix linguae.

Conducting pathways of the taste analyzer



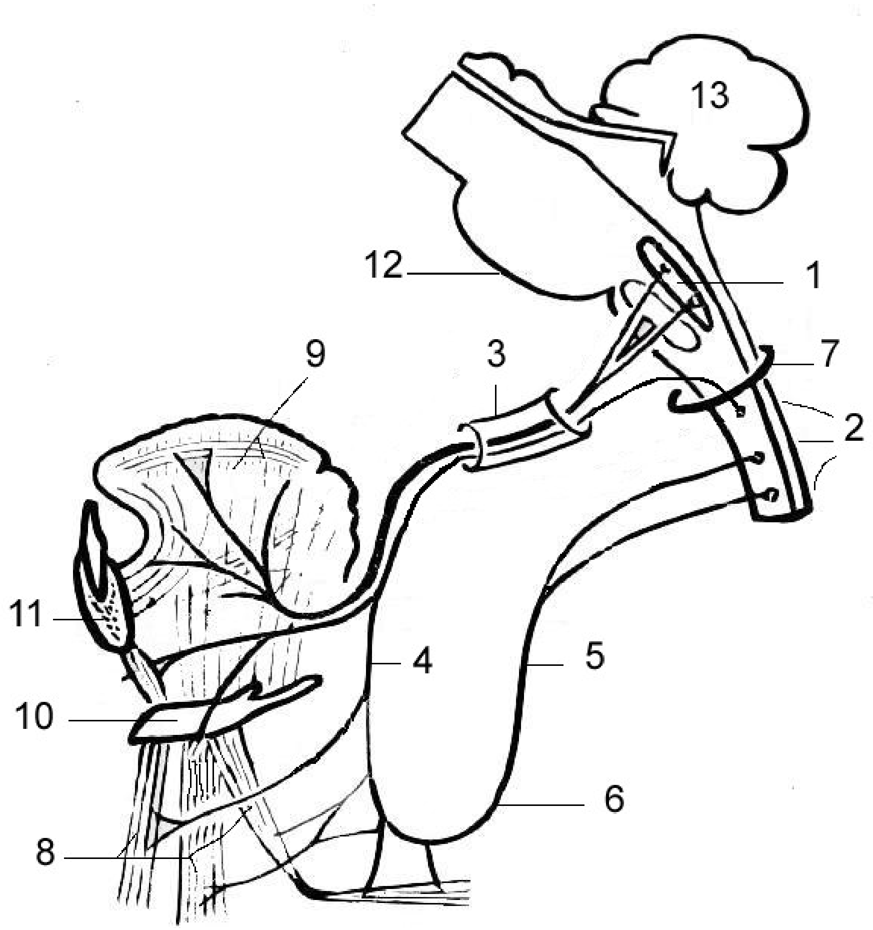
1 – neuronum I (ganglion geniculi, VII);
2 – neuronum I (ganglion inferius, IX);
3 – neuronum I (ganglion inferius, X);
4 – neuronum II [nucleus tractus solitarii (VII, IX, X)];
5 – neuronum III (thalamus opticus);
6 – gyrus parahippocampalis et uncus;
7 – canalis nervi facialis (Fallopius);
8 – foramen jugulare;
9 – lingua.

Conducting pathways of the accessory nerve (XI)

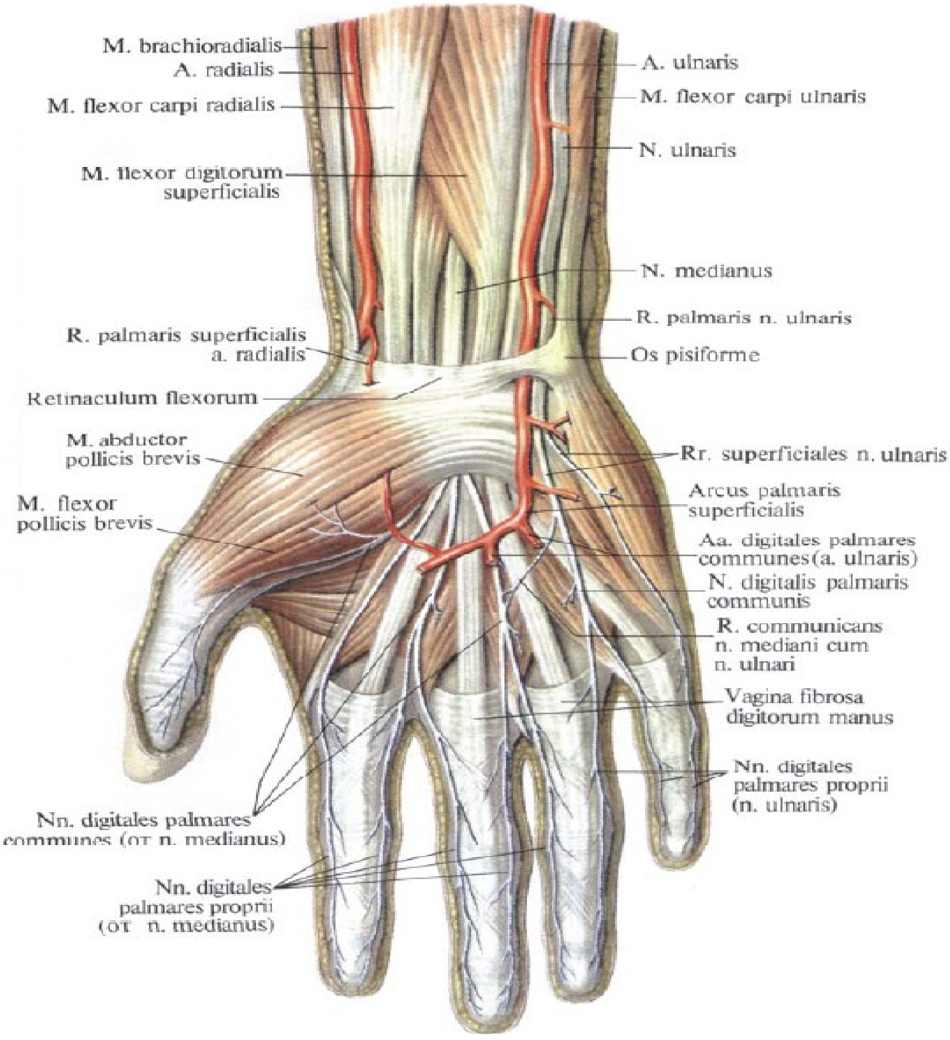


1 – neuronum I (gyrus precentralis, neurocytus pyramidalis magnus, Betz);
2 – neuronum II [nuclei motorii n. accessorii:
a – nucleus ambiguus (IX, X, XI);
b – nucleus spinalis (XI);
3 – foramen occipitale magnum;
4 – foramen jugulare;
5 – mm. sternocleidomastoideus et trapezius;
6 – radices craniales nervi accessorii;
7 – radices spinales nervi accessorii;
8 – ramus externus;
9 – ramus internus;
10 – tractus corticonuclearis.

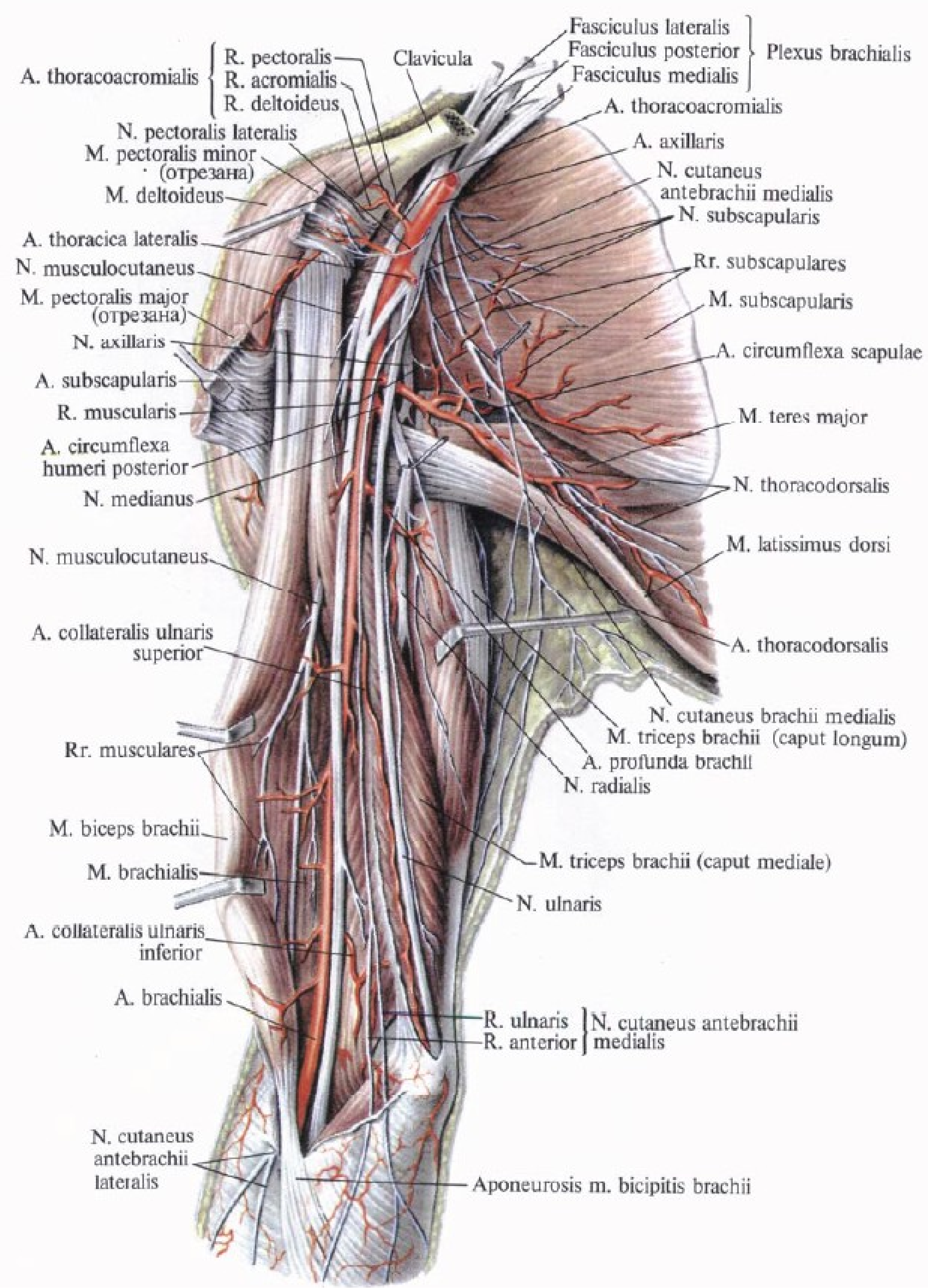
Conducting pathways of the hypoglossal nerve (XII)



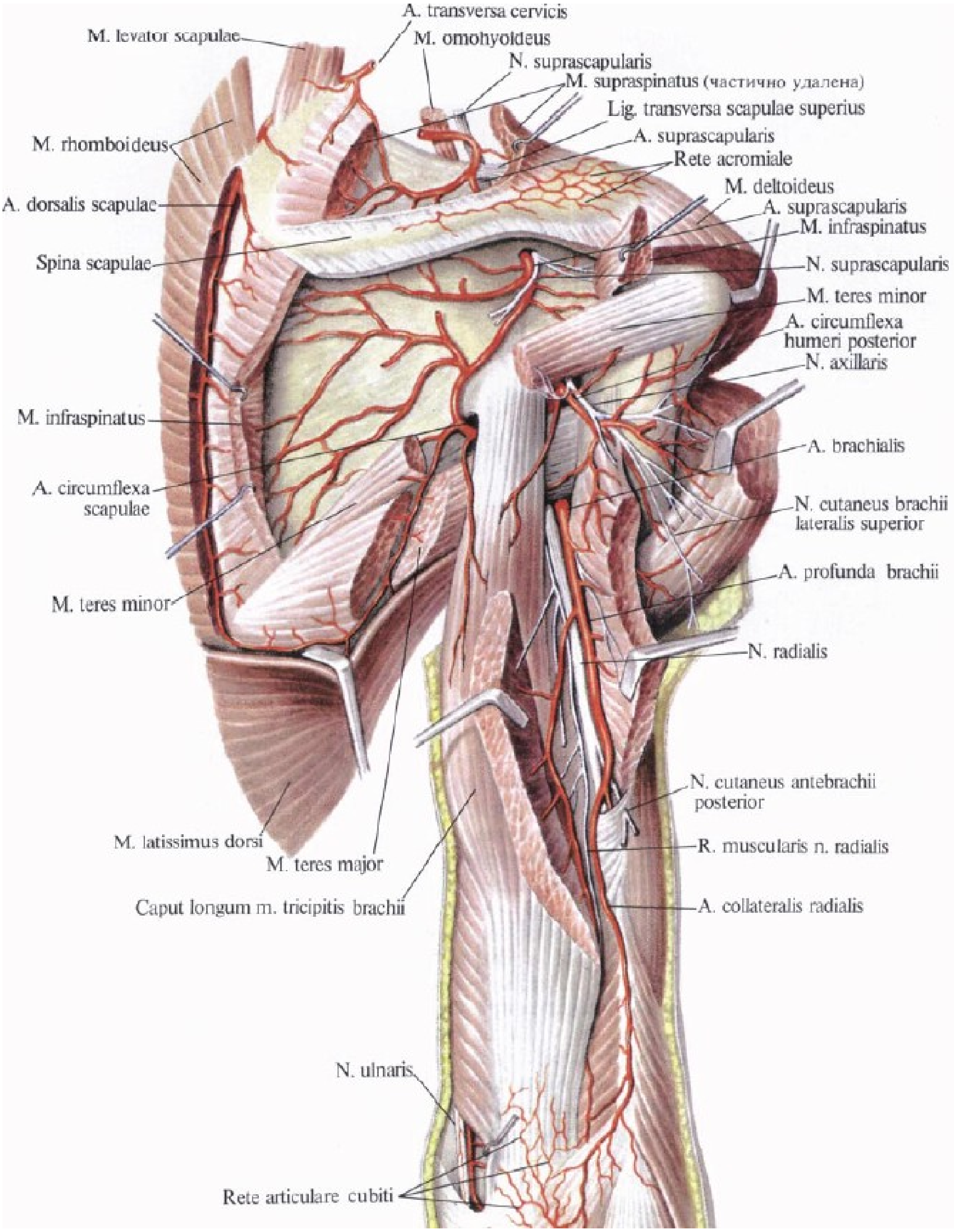
1 – nucleus nervi hypoglossi;
2 – medulla spinalis (segmenti C_1, C_2, C_3);
3 – canalis hypoglossus;
4 – radix superior ansae cervicalis;
5 – radix inferior ansae cervicalis;
6 – ansa cervicalis;
7 – foramen magnum;
8 – mm. infrahyoidei;
9 – rami linguales (musculi linguae);
10 – os hyoideum;
11 – mandibula;
12 – truncus cerebri;
13 – cerebellum.

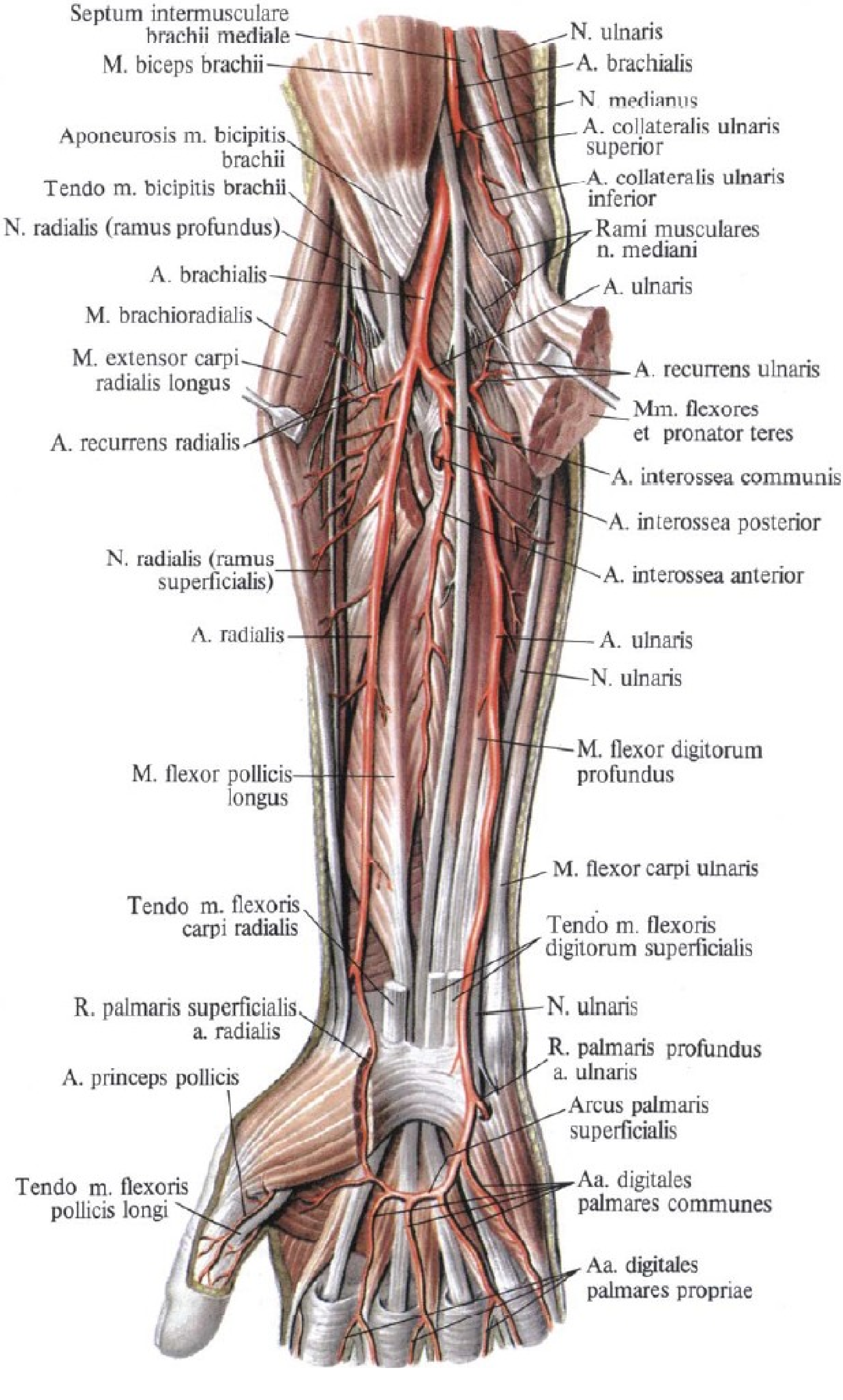


M. brachioradialis
A. radialis
M. flexor carpi radialis
M. flexor digitorum superficialis
R. palmaris superficialis a. radialis
Retinaculum flexorum
M. abductor pollicis brevis
M. flexor pollicis brevis
Nn. digitales palmares communes (от n. medianus)
Nn. digitales palmares proprii (от n. medianus)
A. ulnaris
M. flexor carpi ulnaris
N. ulnaris
N. medianus
R. palmaris n. ulnaris
Os pisiforme
Rr. superficiales n. ulnaris
Arcus palmaris superficialis
Aa. digitales palmares communes (a. ulnaris)
N. digitalis palmaris communis
R. communicans n. mediani cum n. ulnari
Vagina fibrosa digitorum manus
Nn. digitales palmares proprii (n. ulnaris)

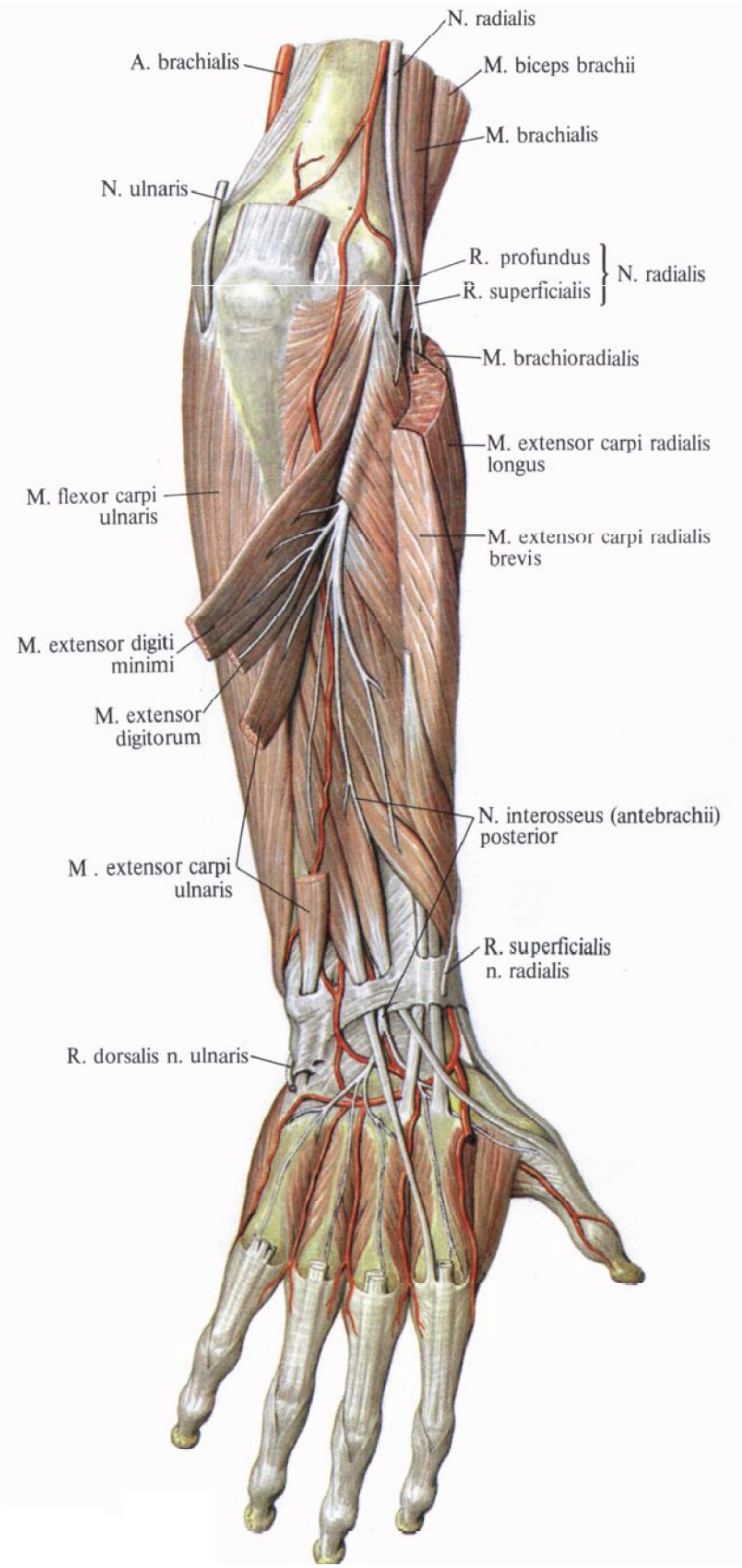


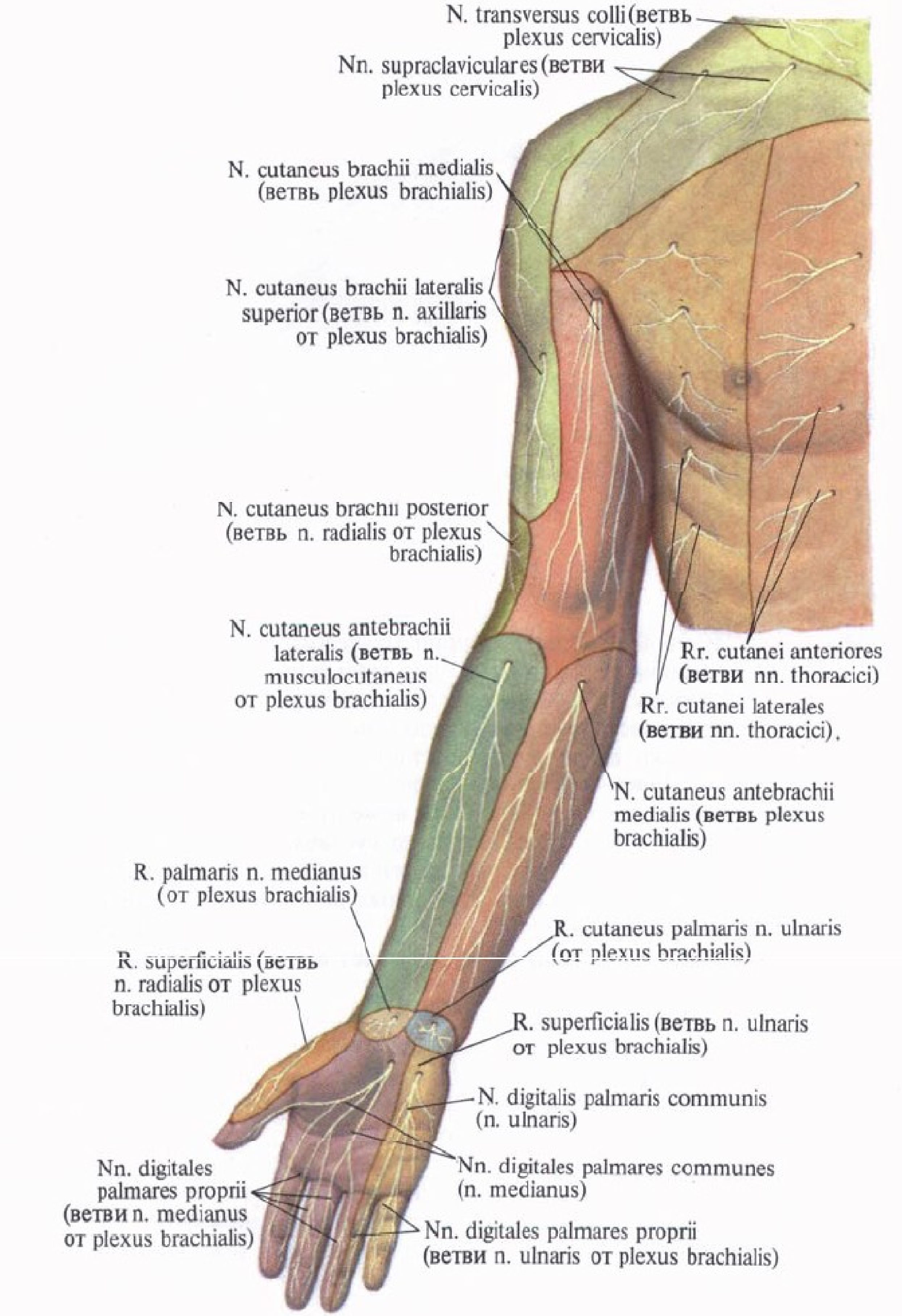
A. thoracoacromialis
R. pectoralis
R. acromialis
R. deltoideus
Clavicula
Fasciculus lateralis
Fasciculus posterior
Fasciculus medialis
Plexus brachialis
A. thoracoacromialis
N. pectoralis lateralis
M. pectoralis minor (отрезана)
M. deltoideus
A. axillaris
N. cutaneus antebrachii medialis
N. subscapularis
A. thoracica lateralis
N. musculocutaneus
Rr. subscapulares
M. pectoralis major (отрезана)
M. subscapularis
N. axillaris
A. circumflexa scapulae
A. subscapularis
R. muscularis
M. teres major
A. circumflexa humeri posterior
N. medianus
N. thoracodorsalis
M. latissimus dorsi
N. musculocutaneus
A. collateralis ulnaris superior
A. thoracodorsalis
N. cutaneus brachii medialis
M. triceps brachii (caput longum)
A. profunda brachii
N. radialis
Rr. musculares
M. biceps brachii
M. brachialis
M. triceps brachii (caput mediale)
N. ulnaris
A. collateralis ulnaris inferior
A. brachialis
R. ulnaris
R. anterior
N. cutaneus antebrachii medialis
N. cutaneus antebrachii lateralis
Aponeurosis m. bicipitis brachii

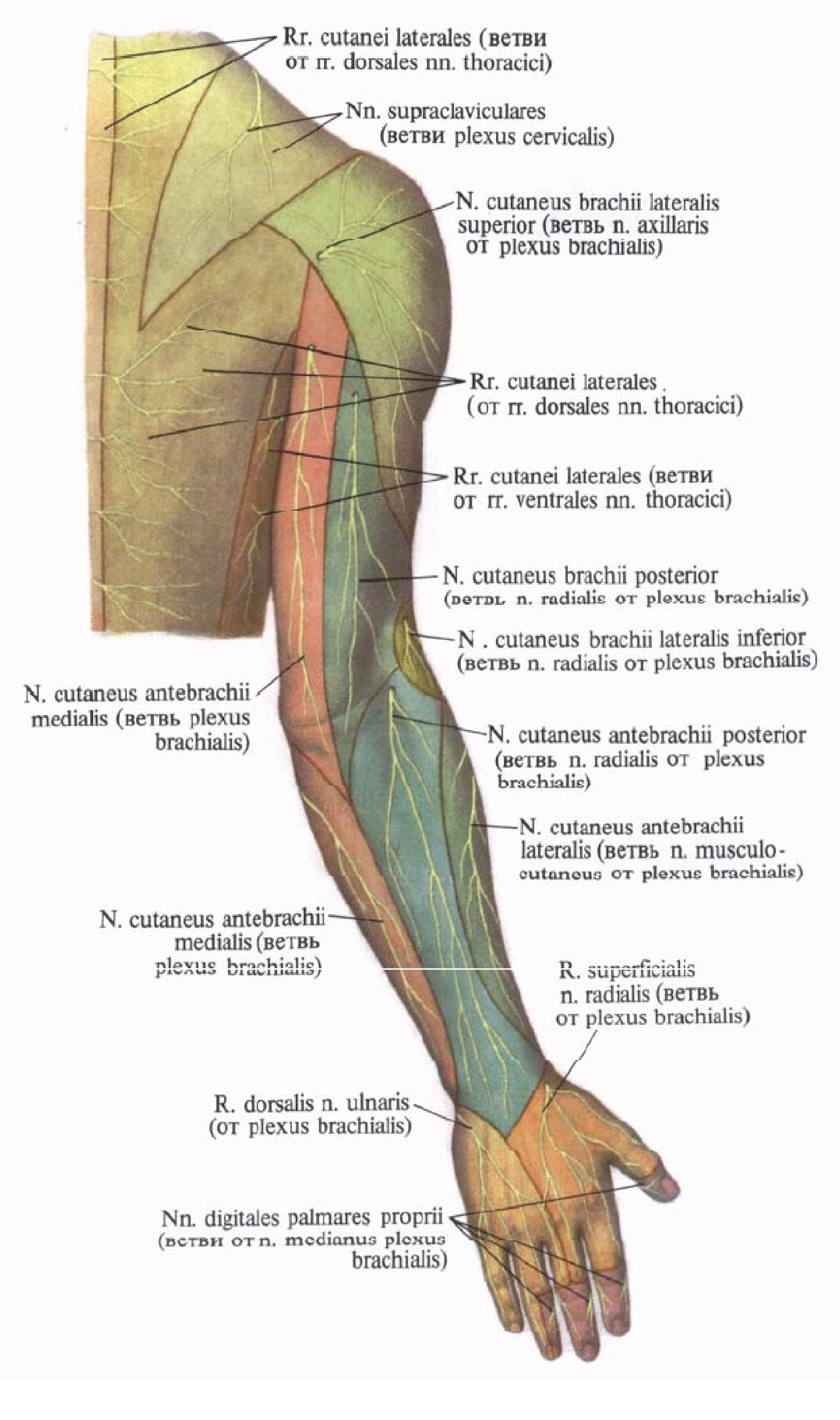

A. transversa cervicis
M. levator scapulae
M. omohyoideus
N. suprascapularis
M. supraspinatus (частично удалена)
Lig. transversa scapulae superius
M. rhomboideus
A. suprascapularis
Rete acromiale
M. deltoideus
A. dorsalis scapulae
A. suprascapularis
M. infraspinatus
Spina scapulae
N. suprascapularis
M. teres minor
A. circumflexa humeri posterior
N. axillaris
M. infraspinatus
A. brachialis
A. circumflexa scapulae
N. cutaneus brachii lateralis superior
A. profunda brachii
M. teres minor
N. radialis
N. cutaneus antebrachii posterior
M. latissimus dorsi
R. muscularis n. radialis
M. teres major
Caput longum m. tricipitis brachii
A. collateralis radialis
N. ulnaris
Rete articulare cubiti



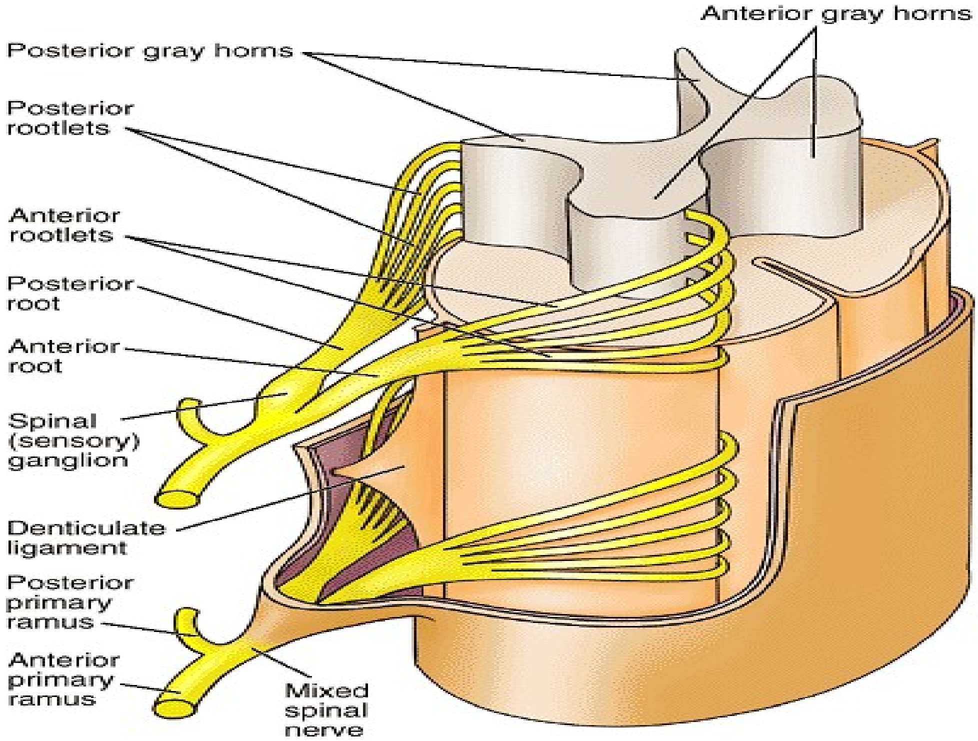
Septum intermusculare brachii mediale
M. biceps brachii
Aponeurosis m. bicipitis brachii
Tendo m. bicipitis brachii
N. radialis (ramus profundus)
A. brachialis
M. brachioradialis
M. extensor carpi radialis longus
A. recurrens radialis
N. radialis (ramus superficialis)
A. radialis
M. flexor pollicis longus
Tendo m. flexoris carpi radialis
R. palmaris superficialis a. radialis
A. princeps pollicis
Tendo m. flexoris pollicis longi
N. ulnaris
A. brachialis
N. medianus
A. collateralis ulnaris superior
A. collateralis ulnaris inferior
Rami musculares n. mediani
A. ulnaris
A. recurrens ulnaris
Mm. flexores et pronator teres
A. interossea communis
A. interossea posterior
A. interossea anterior
A. ulnaris
N. ulnaris
M. flexor digitorum profundus
M. flexor carpi ulnaris
Tendo m. flexoris digitorum superficialis
N. ulnaris
R. palmaris profundus a. ulnaris
Arcus palmaris superficialis
Aa. digitales palmares communes
Aa. digitales palmares propriae

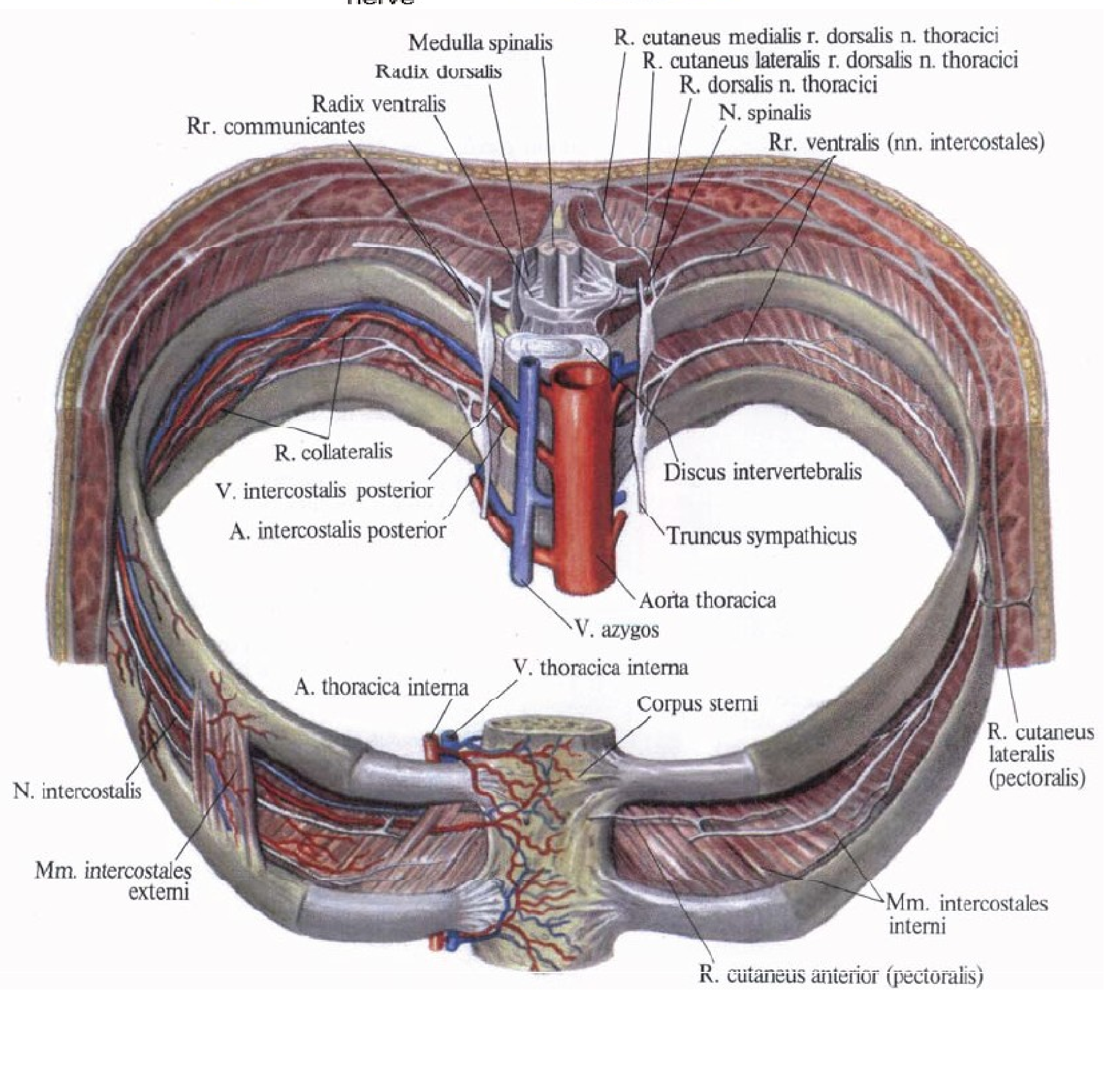

N. radialis
A. brachialis
M. biceps brachii
M. brachialis
N. ulnaris
R. profundus
R. superficialis
N. radialis
M. brachioradialis
M. extensor carpi radialis longus
M. flexor carpi ulnaris
M. extensor carpi radialis brevis
M. extensor digiti minimi
M. extensor digitorum
N. interosseus (antebrachii) posterior
M . extensor carpi ulnaris
R. superficialis n. radialis
R. dorsalis n. ulnaris

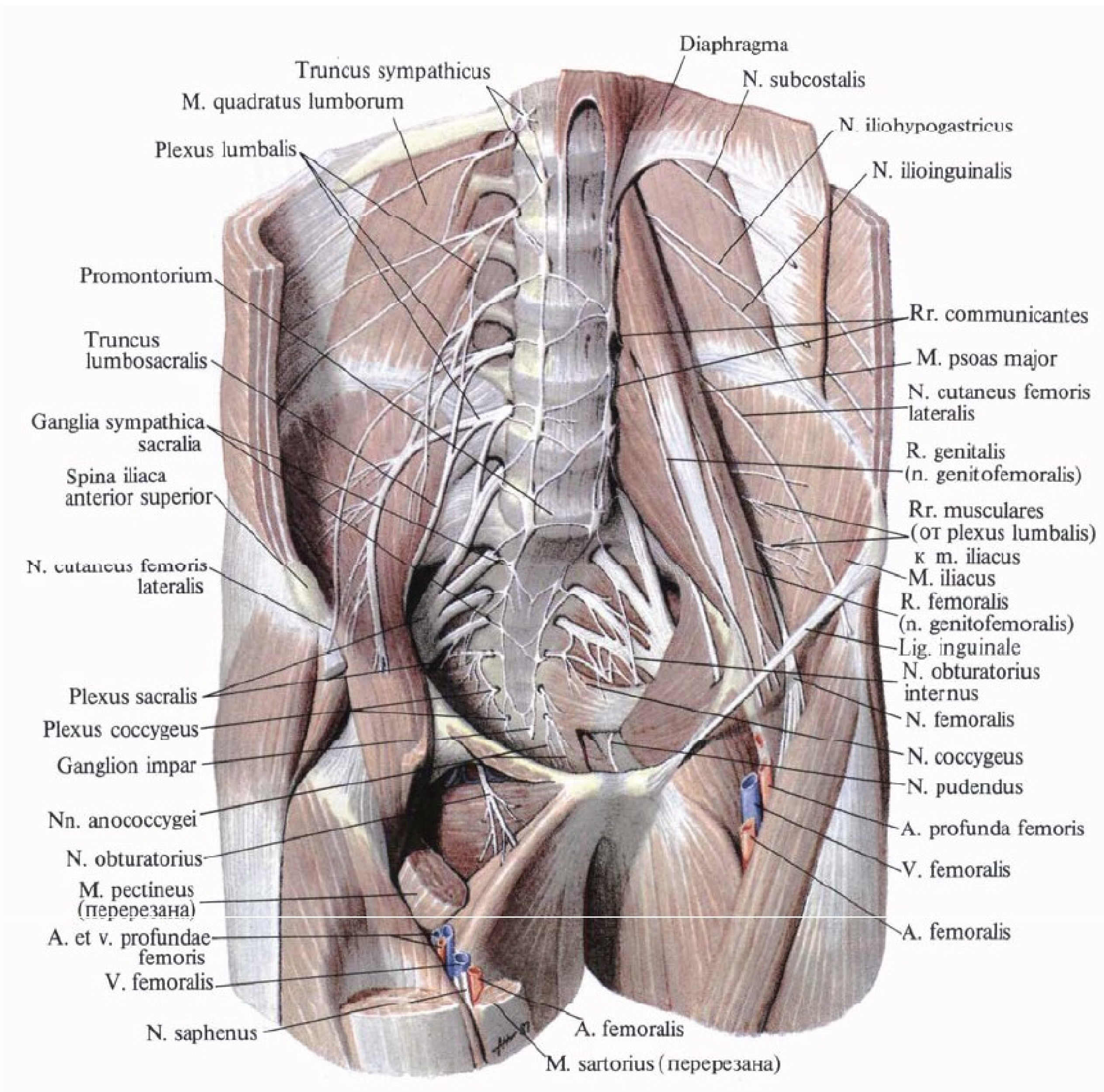

N. transversus colli (ветвь plexus cervicalis)
Nn. supraclaviculares (ветви plexus cervicalis)
N. cutaneus brachii medialis (ветвь plexus brachialis)
N. cutaneus brachii lateralis superior (ветвь n. axillaris от plexus brachialis)
N. cutaneus brachii posterior (ветвь n. radialis от plexus brachialis)
N. cutaneus antebrachii lateralis (ветвь n. musculocutaneus от plexus brachialis)
Rr. cutanei anteriores (ветви nn. thoracici)
Rr. cutanei laterales (ветви nn. thoracici).
N. cutaneus antebrachii medialis (ветвь plexus brachialis)
R. palmaris n. medianus (от plexus brachialis)
R. cutaneus palmaris n. ulnaris (от plexus brachialis)
R. superficialis (ветвь n. radialis от plexus brachialis)
R. superficialis (ветвь n. ulnaris от plexus brachialis)
N. digitalis palmaris communis (n. ulnaris)
Nn. digitales palmares communes (n. medianus)
Nn. digitales palmares proprii (ветви n. medianus от plexus brachialis)
Nn. digitales palmares proprii (ветви n. ulnaris от plexus brachialis)

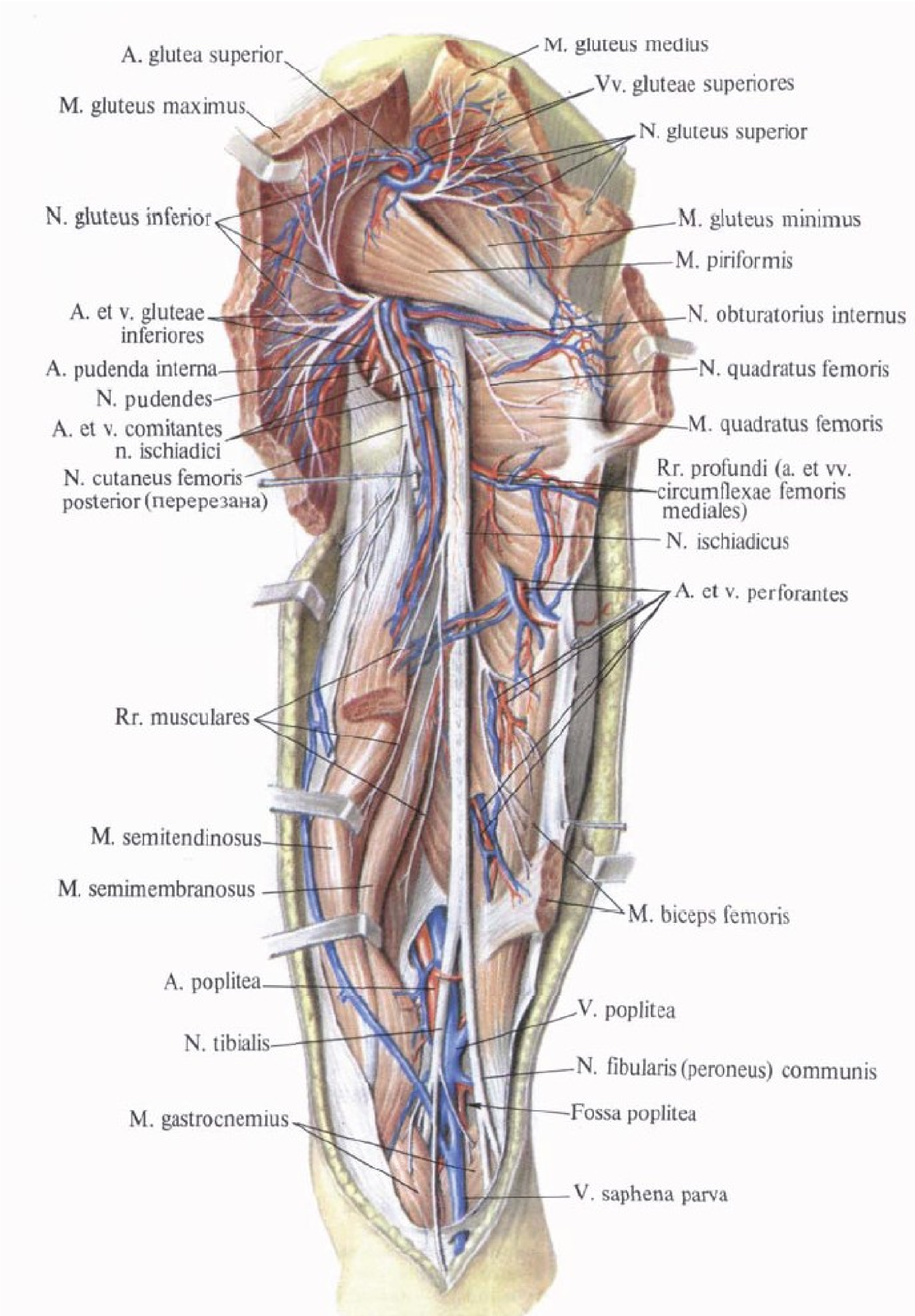


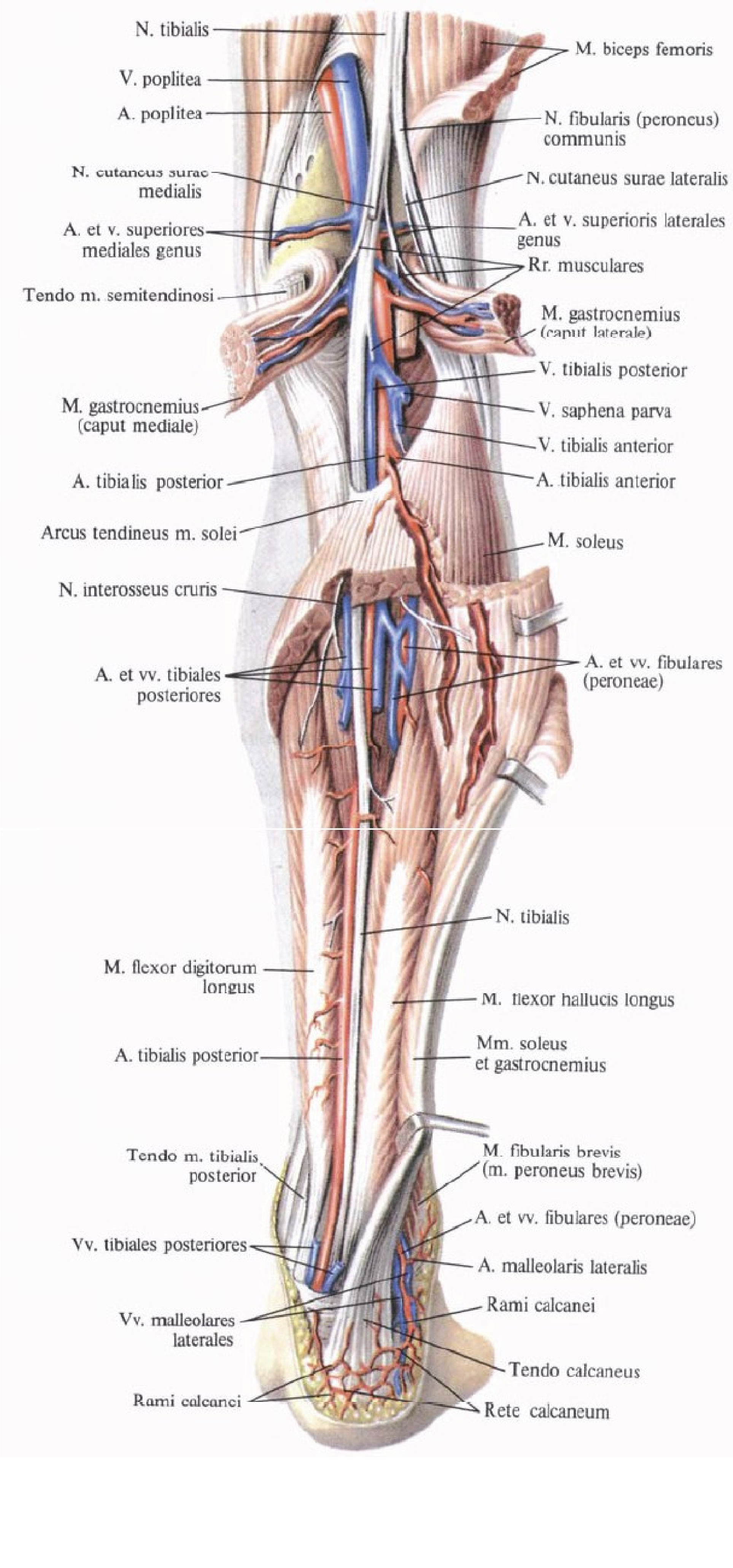
Rr. cutanei laterales (ветви от rr. dorsales nn. thoracici)
Nn. supraclaviculares (ветви plexus cervicalis)
N. cutaneus brachii lateralis superior (ветвь n. axillaris от plexus brachialis)
Rr. cutanei laterales (от rr. dorsales nn. thoracici)
Rr. cutanei laterales (ветви от rr. ventrales nn. thoracici)
N. cutaneus brachii posterior (ветвь n. radialis от plexus brachialis)
N . cutaneus brachii lateralis inferior (ветвь n. radialis от plexus brachialis)
N. cutaneus antebrachii medialis (ветвь plexus brachialis)
N. cutaneus antebrachii posterior (ветвь n. radialis от plexus brachialis)
N. cutaneus antebrachii lateralis (ветвь n. musculo-cutaneus от plexus brachialis)
N. cutaneus antebrachii medialis (ветвь plexus brachialis)
R. superficialis n. radialis (ветвь от plexus brachialis)
R. dorsalis n. ulnaris (от plexus brachialis)
Nn. digitales palmares proprii (ветви от n. medianus plexus brachialis)

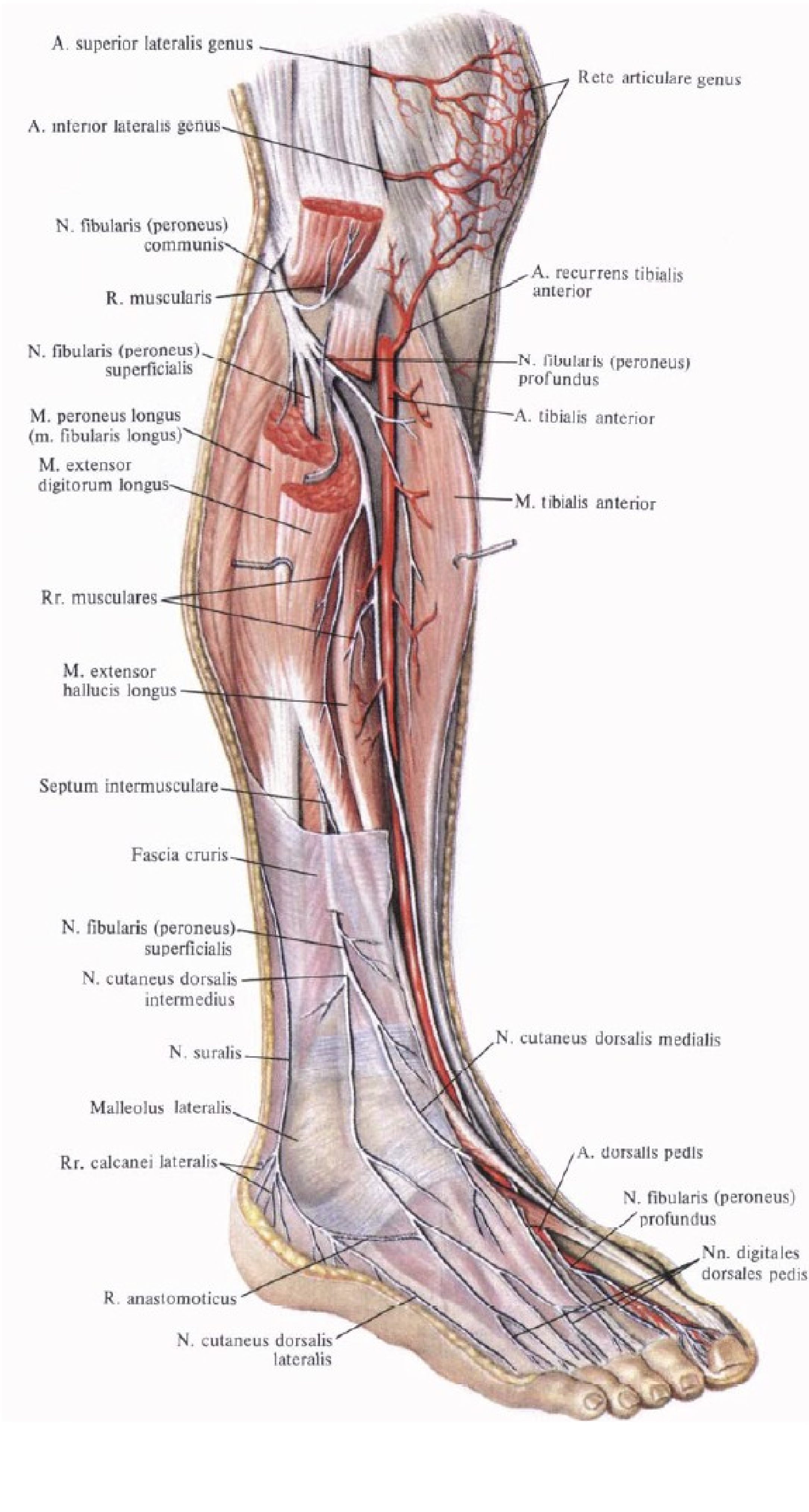

Anterior gray horns
Posterior gray horns
Posterior rootlets
Anterior rootlets
Posterior root
Anterior root
Spinal (sensory) ganglion
Denticulate ligament
Posterior primary ramus
Anterior primary ramus
Mixed spinal nerve

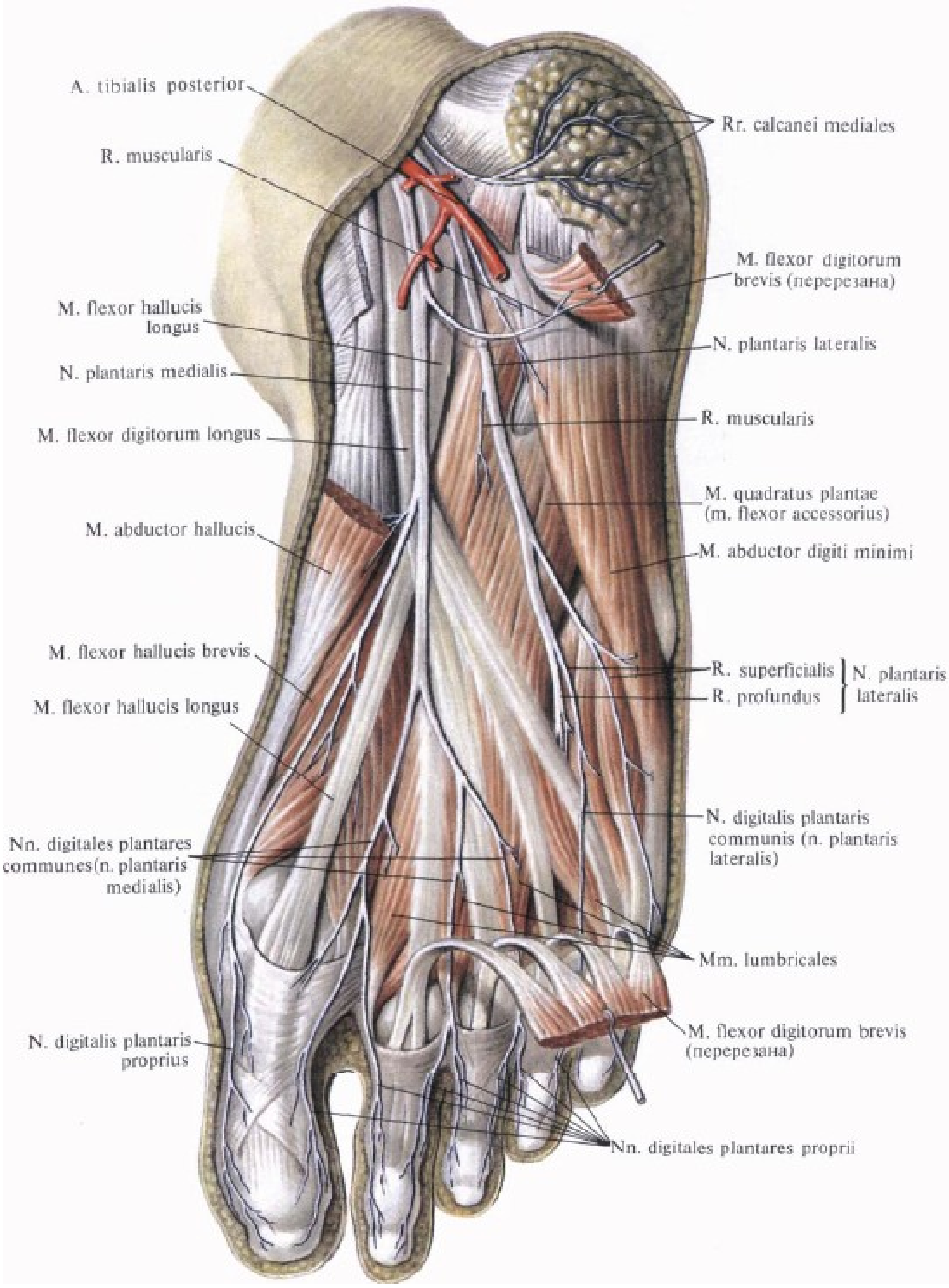

Medulla spinalis
Radix dorsalis
Radix ventralis
Rr. communicantes
R. cutaneus medialis r. dorsalis n. thoracici
R. cutaneus lateralis r. dorsalis n. thoracici
R. dorsalis n. thoracici
N. spinalis
Rr. ventralis (nn. intercostales)
R. collateralis
V. intercostalis posterior
A. intercostalis posterior
Discus intervertebralis
Truncus sympathicus
Aorta thoracica
V. azygos
V. thoracica interna
A. thoracica interna
Corpus sterni
R. cutaneus lateralis (pectoralis)
N. intercostalis
Mm. intercostales externi
Mm. intercostales interni
R. cutaneus anterior (pectoralis)

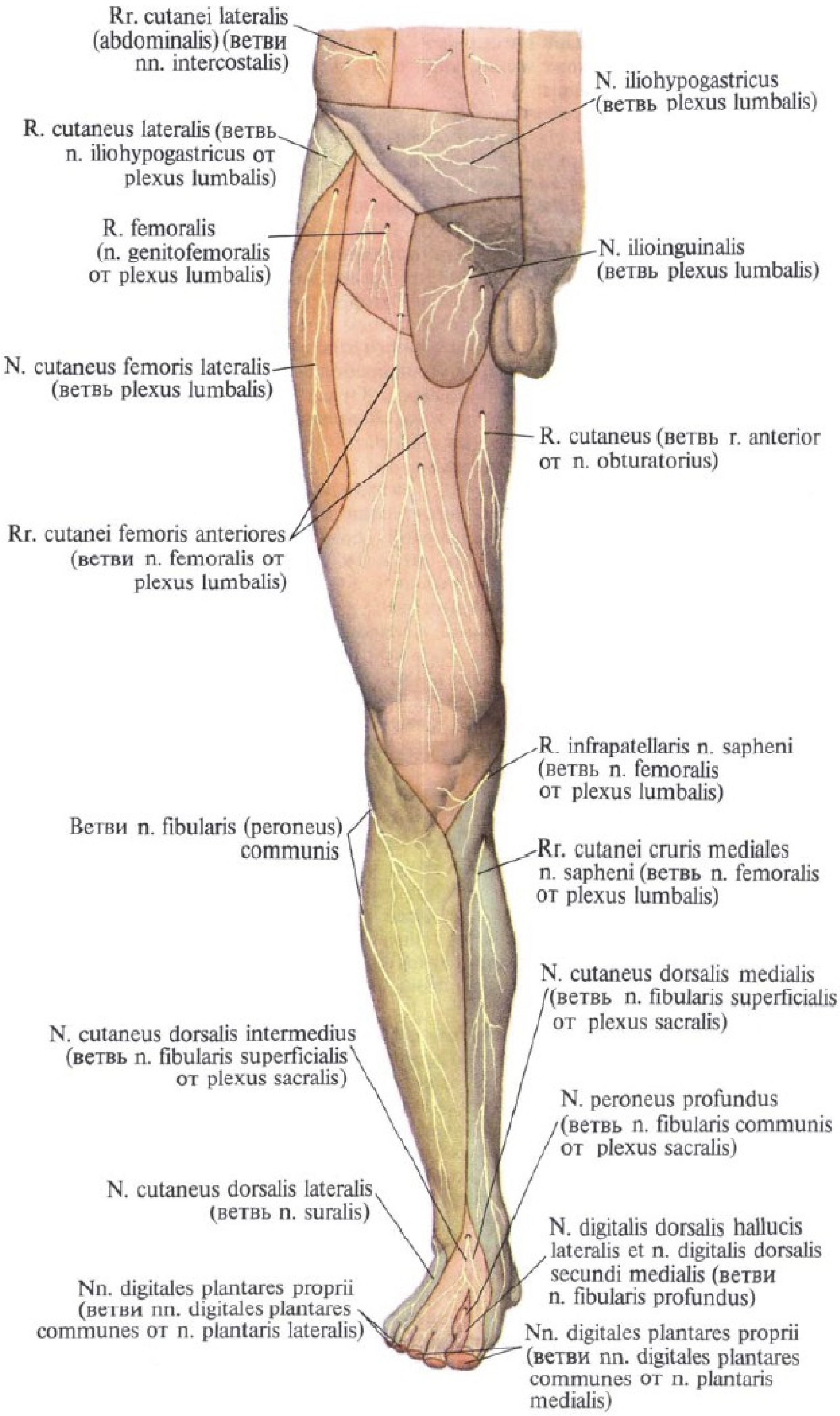

Diaphragma
Truncus sympathicus
N. subcostalis
M. quadratus lumborum
N. iliohypogastricus
Plexus lumbalis
N. ilioinguinalis
Promontorium
Rr. communicantes
Truncus lumbosacralis
M. psoas major
N. cutaneus femoris lateralis
Ganglia sympathica sacralia
R. genitalis (n. genitofemoralis)
Spina iliaca anterior superior
Rr. musculares (от plexus lumbalis) к m. iliacus
N. cutaneus femoris lateralis
M. iliacus
R. femoralis (n. genitofemoralis)
Lig. inguinale
N. obturatorius internus
Plexus sacralis
N. femoralis
Plexus coccygeus
N. coccygeus
Ganglion impar
N. pudendus
Nn. anococcygei
A. profunda femoris
N. obturatorius
V. femoralis
M. pectineus (перерезана)
A. femoralis
A. et v. profundae femoris
V. femoralis
A. femoralis
N. saphenus
M. sartorius (перерезана)


A. glutea superior
M. gluteus medius
M. gluteus maximus
Vv. gluteae superiores
N. gluteus superior
N. gluteus inferior
M. gluteus minimus
M. piriformis
A. et v. gluteae inferiores
N. obturatorius internus
A. pudenda interna
N. quadratus femoris
N. pudendes
A. et v. comitantes n. ischiadici
M. quadratus femoris
N. cutaneus femoris posterior (перерезана)
Rr. profundi (a. et vv. circumflexae femoris mediales)
N. ischiadicus
A. et v. perforantes
Rr. musculares
M. semitendinosus
M. semimembranosus
M. biceps femoris
A. poplitea
V. poplitea
N. tibialis
N. fibularis (peroneus) communis
M. gastrocnemius
Fossa poplitea
V. saphena parva

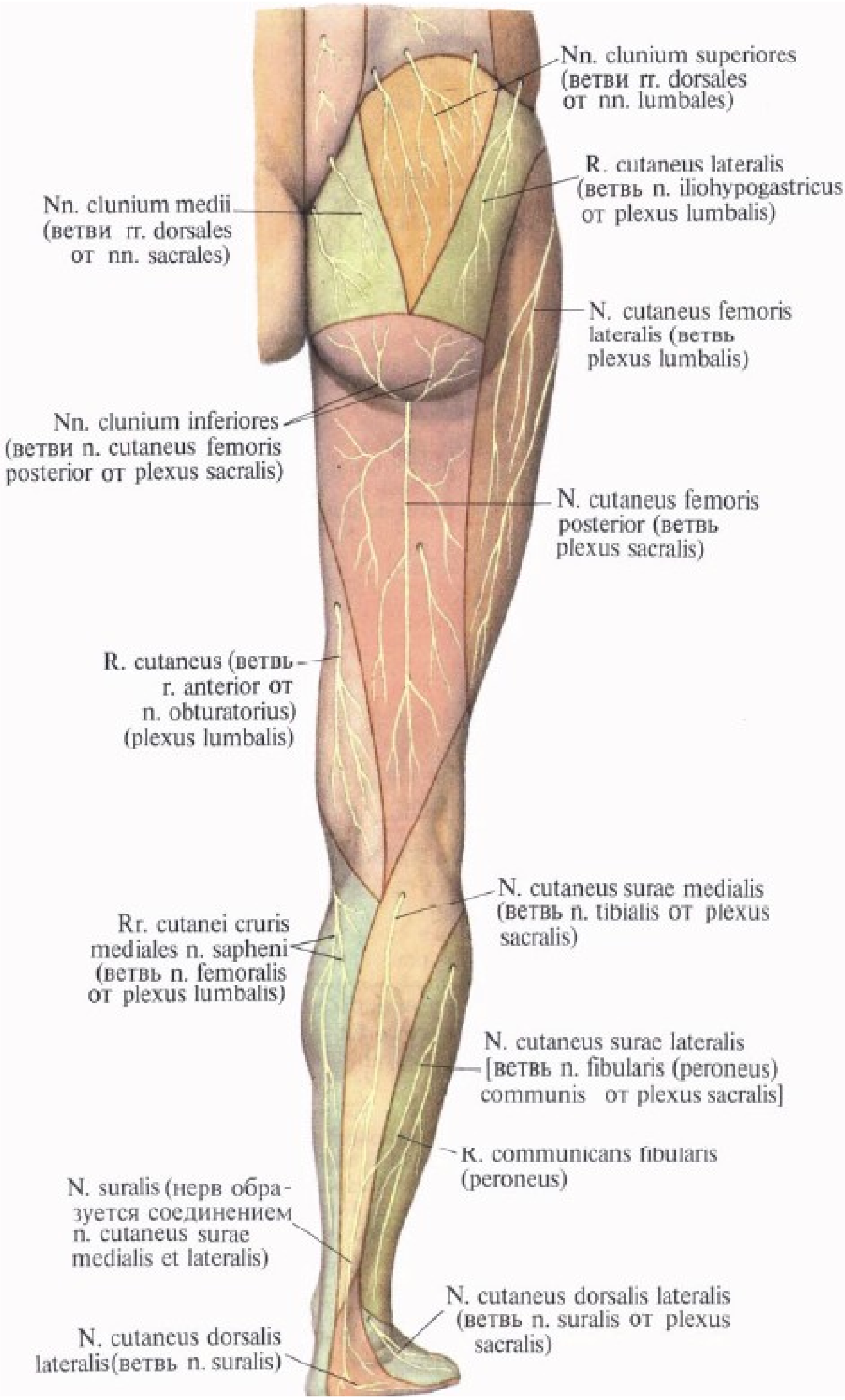

N. tibialis
V. poplitea
A. poplitea
N. cutaneus surae medialis
A. et v. superiores mediales genus
Tendo m. semitendinosi
M. gastrocnemius (caput mediale)
A. tibialis posterior
Arcus tendineus m. solei
N. interosseus cruris
A. et vv. tibiales posteriores
M. biceps femoris
N. fibularis (peroneus) communis
N. cutaneus surae lateralis
A. et v. superioris laterales genus
Rr. musculares
M. gastrocnemius (caput laterale)
V. tibialis posterior
V. saphena parva
V. tibialis anterior
A. tibialis anterior
M. soleus
A. et vv. fibulares (peroneae)
N. tibialis
M. flexor digitorum longus
M. flexor hallucis longus
A. tibialis posterior
Mm. soleus et gastrocnemius
Tendo m. tibialis posterior
M. fibularis brevis (m. peroneus brevis)
A. et vv. fibulares (peroneae)
Vv. tibiales posteriores
A. malleolaris lateralis
Vv. malleolares laterales
Rami calcanei
Tendo calcaneus
Rami calcanei
Rete calcaneum

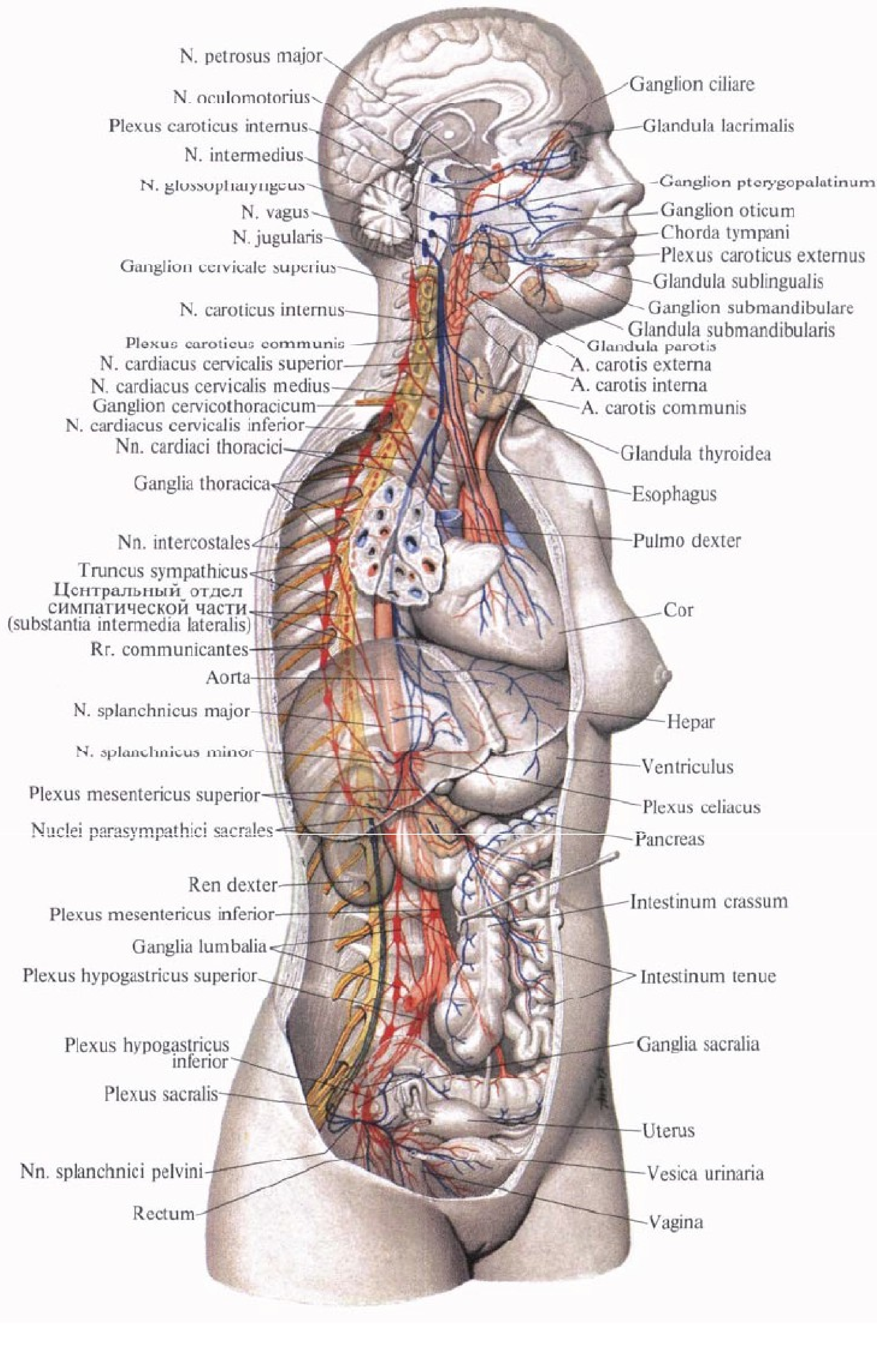

A. superior lateralis genus
Rete articulare genus
A. inferior lateralis genus
N. fibularis (peroneus) communis
A. recurrens tibialis anterior
R. muscularis
N. fibularis (peroneus) superficialis
N. fibularis (peroneus) profundus
M. peroneus longus (m. fibularis longus)
A. tibialis anterior
M. extensor digitorum longus
M. tibialis anterior
Rr. musculares
M. extensor hallucis longus
Septum intermusculare
Fascia cruris
N. fibularis (peroneus) superficialis
N. cutaneus dorsalis intermedius
N. cutaneus dorsalis medialis
N. suralis
Malleolus lateralis
A. dorsalis pedis
Rr. calcanei lateralis
N. fibularis (peroneus) profundus
Nn. digitales dorsales pedis
R. anastomoticus
N. cutaneus dorsalis lateralis


A. tibialis posterior
R. muscularis
M. flexor hallucis longus
N. plantaris medialis
M. flexor digitorum longus
M. abductor hallucis
M. flexor hallucis brevis
M. flexor hallucis longus
Nn. digitales plantares communes (n. plantaris medialis)
N. digitalis plantaris proprius
Rr. calcanei mediales
M. flexor digitorum brevis (перерезана)
N. plantaris lateralis
R. muscularis
M. quadratus plantae (m. flexor accessorius)
M. abductor digiti minimi
R. superficialis
R. profundus
N. plantaris lateralis
N. digitalis plantaris communis (n. plantaris lateralis)
Mm. lumbricales
M. flexor digitorum brevis (перерезана)
Nn. digitales plantares proprii



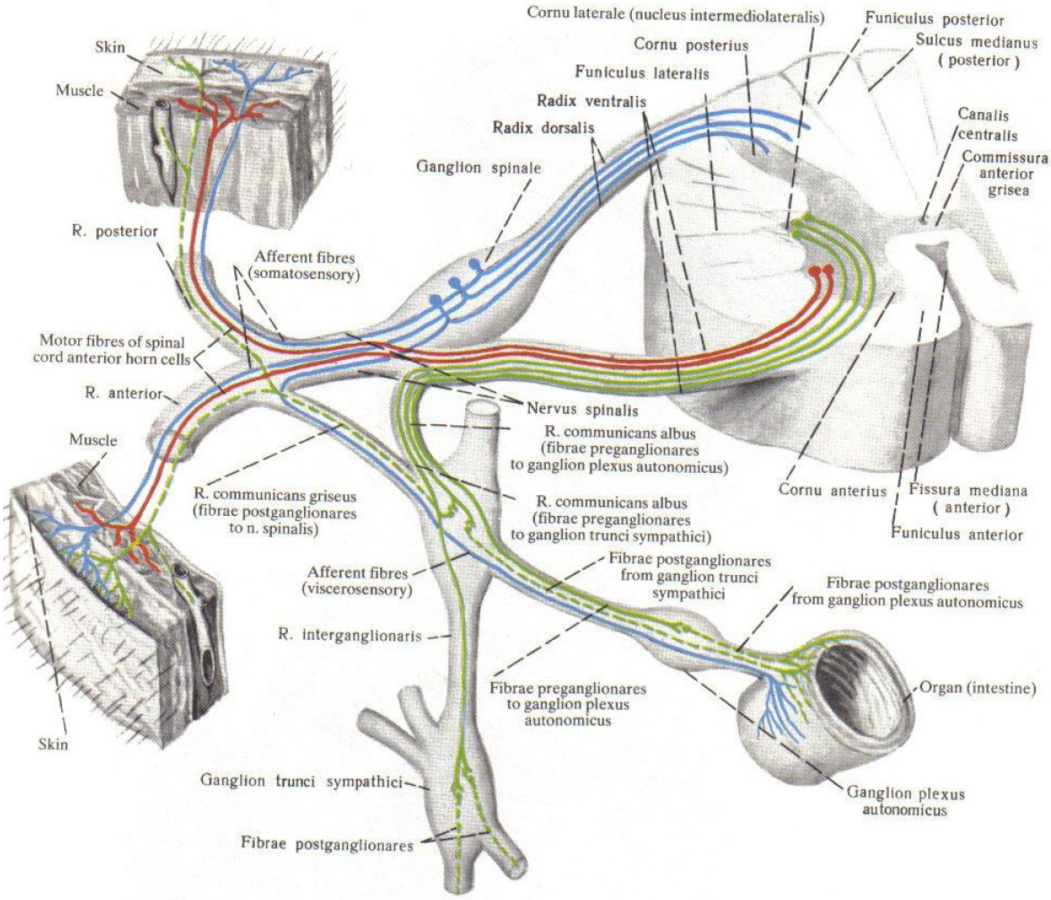
Rr. cutanei lateralis (abdominalis) (ветви nn. intercostalis)
N. iliohypogastricus (ветвь plexus lumbalis)
R. cutaneus lateralis (ветвь n. iliohypogastricus от plexus lumbalis)
R. femoralis (n. genitofemoralis от plexus lumbalis)
N. ilioinguinalis (ветвь plexus lumbalis)
N. cutaneus femoris lateralis (ветвь plexus lumbalis)
R. cutaneus (ветвь r. anterior от n. obturatorius)
Rr. cutanei femoris anteriores (ветви n. femoralis от plexus lumbalis)
R. infrapatellaris n. sapheni (ветвь n. femoralis от plexus lumbalis)
Ветви n. fibularis (peroneus) communis
Rr. cutanei cruris mediales n. sapheni (ветвь n. femoralis от plexus lumbalis)
N. cutaneus dorsalis medialis (ветвь n. fibularis superficialis от plexus sacralis)
N. cutaneus dorsalis intermedius (ветвь n. fibularis superficialis от plexus sacralis)
N. peroneus profundus (ветвь n. fibularis communis от plexus sacralis)
N. cutaneus dorsalis lateralis (ветвь n. suralis)
N. digitalis dorsalis hallucis lateralis et n. digitalis dorsalis secundi medialis (ветви n. fibularis profundus)
Nn. digitales plantares proprii (ветви nn. digitales plantares communes от n. plantaris lateralis)
Nn. digitales plantares proprii (ветви nn. digitales plantares communes от n. plantaris medialis)

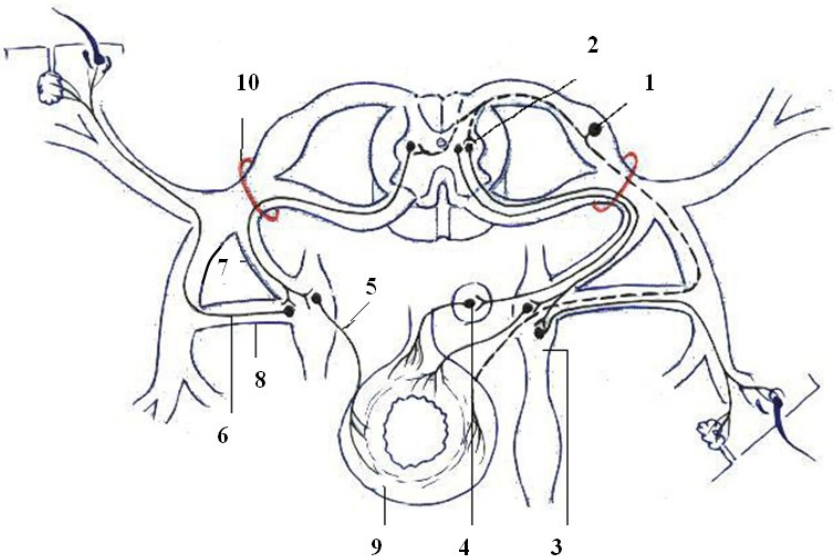

Nn. clunium superiores (ветви rr. dorsales от nn. lumbales)
R. cutaneus lateralis (ветвь n. iliohypogastricus от plexus lumbalis)
Nn. clunium medii (ветви rr. dorsales от nn. sacrales)
N. cutaneus femoris lateralis (ветвь plexus lumbalis)
Nn. clunium inferiores (ветви n. cutaneus femoris posterior от plexus sacralis)
N. cutaneus femoris posterior (ветвь plexus sacralis)
R. cutaneus (ветвь r. anterior от n. obturatorius) (plexus lumbalis)
N. cutaneus surae medialis (ветвь n. tibialis от plexus sacralis)
Rr. cutanei cruris mediales n. sapheni (ветвь n. femoralis от plexus lumbalis)
N. cutaneus surae lateralis [ветвь n. fibularis (peroneus) communis от plexus sacralis]
R. communicans fibularis (peroneus)
N. suralis (нерв образуется соединением n. cutaneus surae medialis et lateralis)
N. cutaneus dorsalis lateralis (ветвь n. suralis от plexus sacralis)
N. cutaneus dorsalis lateralis(ветвь n. suralis)



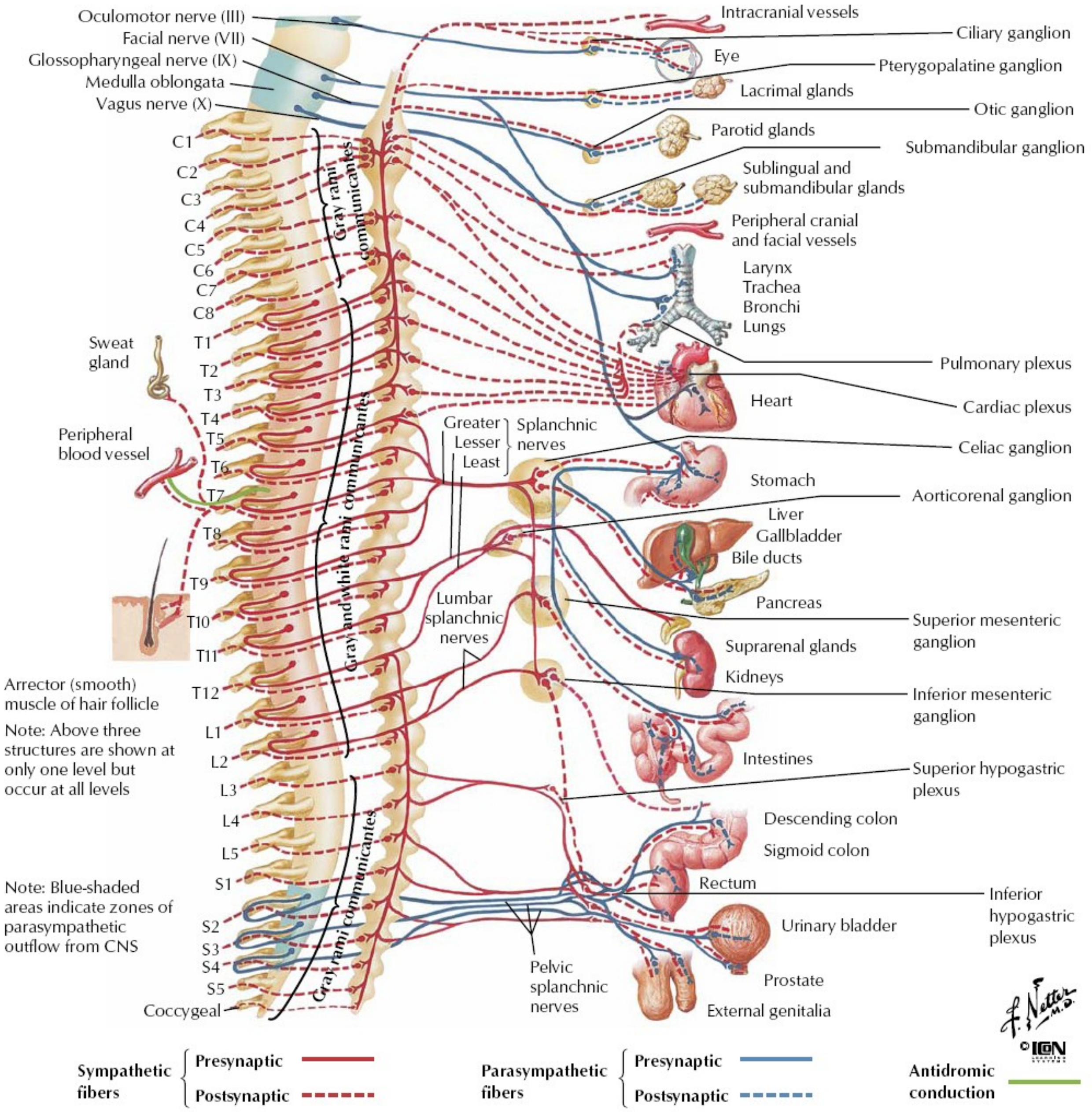
N. petrosus major
N. oculomotorius
Plexus caroticus internus
N. intermedius
N. glossopharyngeus
N. vagus
N. jugularis
Ganglion cervicale superius
N. caroticus internus
Plexus caroticus communis
N. cardiacus cervicalis superior
N. cardiacus cervicalis medius
Ganglion cervicothoracicum
N. cardiacus cervicalis inferior
Nn. cardiaci thoracici
Ganglia thoracica
Nn. intercostales
Truncus sympathicus
Центральный отдел симпатической части (substantia intermedia lateralis)
Rr. communicantes
Aorta
N. splanchnicus major
N. splanchnicus minor
Plexus mesentericus superior
Nuclei parasympathici sacrales
Ren dexter
Plexus mesentericus inferior
Ganglia lumbalia
Plexus hypogastricus superior
Plexus hypogastricus inferior
Plexus sacralis
Nn. splanchnici pelvini
Rectum
Ganglion ciliare
Glandula lacrimalis
Ganglion pterygopalatinum
Ganglion oticum
Chorda tympani
Plexus caroticus externus
Glandula sublingualis
Ganglion submandibulare
Glandula submandibularis
Glandula parotis
A. carotis externa
A. carotis interna
A. carotis communis
Glandula thyroidea
Esophagus
Pulmo dexter
Cor
Hepar
Ventriculus
Plexus celiacus
Pancreas
Intestinum crassum
Intestinum tenue
Ganglia sacralia
Uterus
Vesica urinaria
Vagina

Vegetative (sympathetic) reflex arc





1 – ganglion spinale (neuronum I);
2 – cornu laterale, nucleus intermediolateralis (C_8, Th_{1-12}, L_{1-3}) (neuronum II);
3 – ganglion trunci sympatici (neuronum III);
4 – ganglion praevertebrale (neuronum III);
5 – pars visceralis;
6 – pars somatica;
7 – ramus communicans albus;
8 – ramus communicans griseus;
9 – viscerus;
10 – foramen intervertebrale.



Oculomotor nerve (III)
Facial nerve (VII)
Glossopharyngeal nerve (IX)
Medulla oblongata
Vagus nerve (X)
C1
C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Coccygeal
Gray rami communicantes
Gray and white rami communicantes
Gray rami communicantes
Sweat gland
Peripheral blood vessel
Arrector (smooth) muscle of hair follicle
Note: Above three structures are shown at only one level but occur at all levels
Note: Blue-shaded areas indicate zones of parasympathetic outflow from CNS
Intracranial vessels
Ciliary ganglion
Eye
Pterygopalatine ganglion
Lacrimal glands
Otic ganglion
Parotid glands
Submandibular ganglion
Sublingual and submandibular glands
Peripheral cranial and facial vessels
Larynx
Trachea
Bronchi
Lungs
Pulmonary plexus
Heart
Cardiac plexus
Greater
Lesser
Least
Splanchnic nerves
Celiac ganglion
Stomach
Aorticorenal ganglion
Liver
Gallbladder
Bile ducts
Pancreas
Lumbar splanchnic nerves
Superior mesenteric ganglion
Suprarenal glands
Kidneys
Inferior mesenteric ganglion
Intestines
Superior hypogastric plexus
Descending colon
Sigmoid colon
Rectum
Inferior hypogastric plexus
Urinary bladder
Prostate
Pelvic splanchnic nerves
External genitalia
F. Netter M.D.
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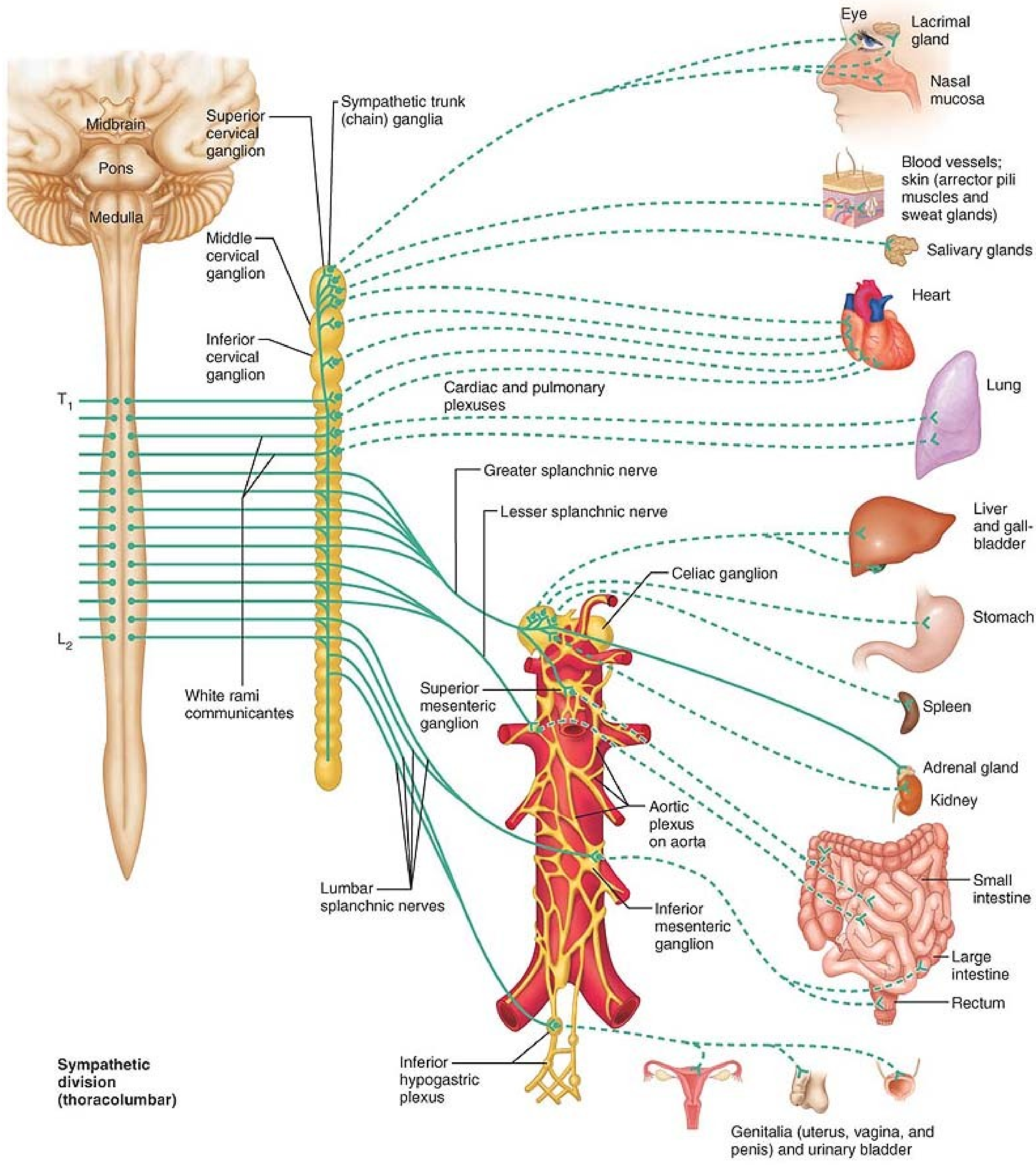
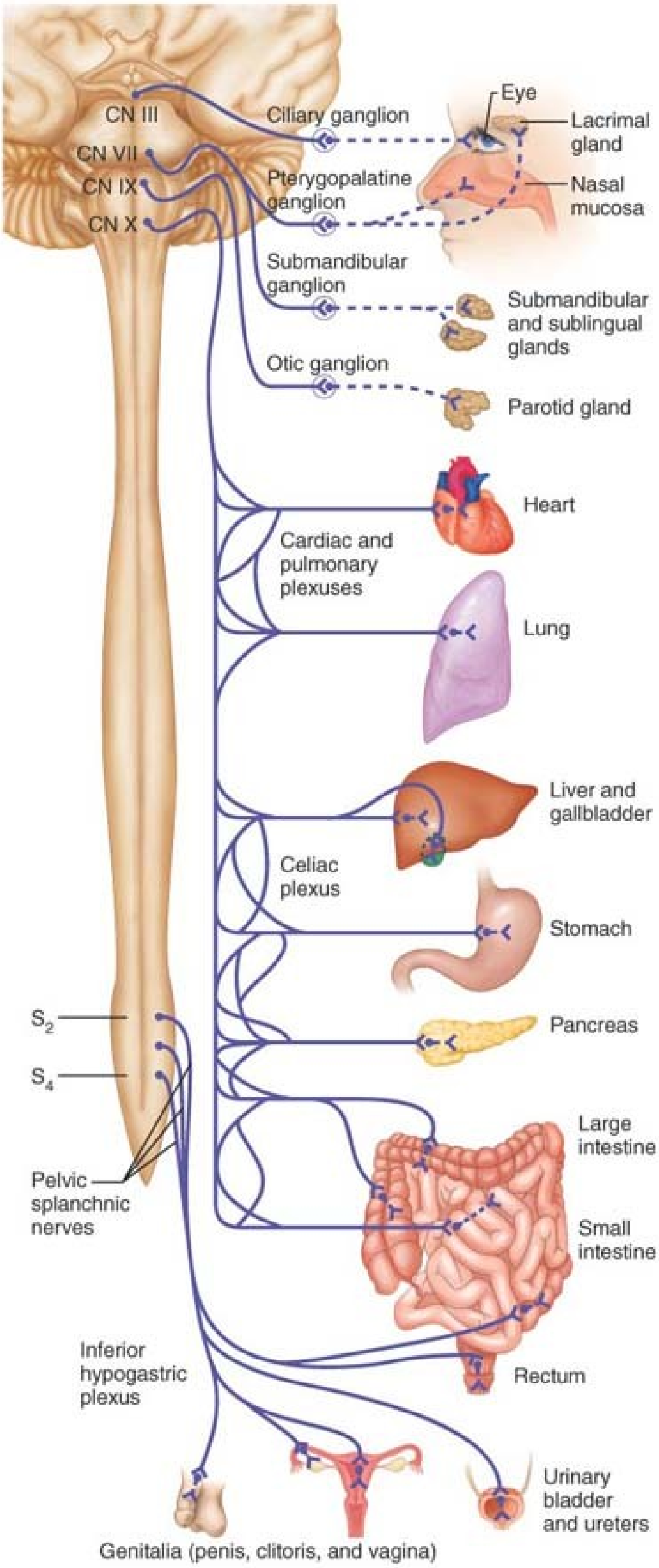
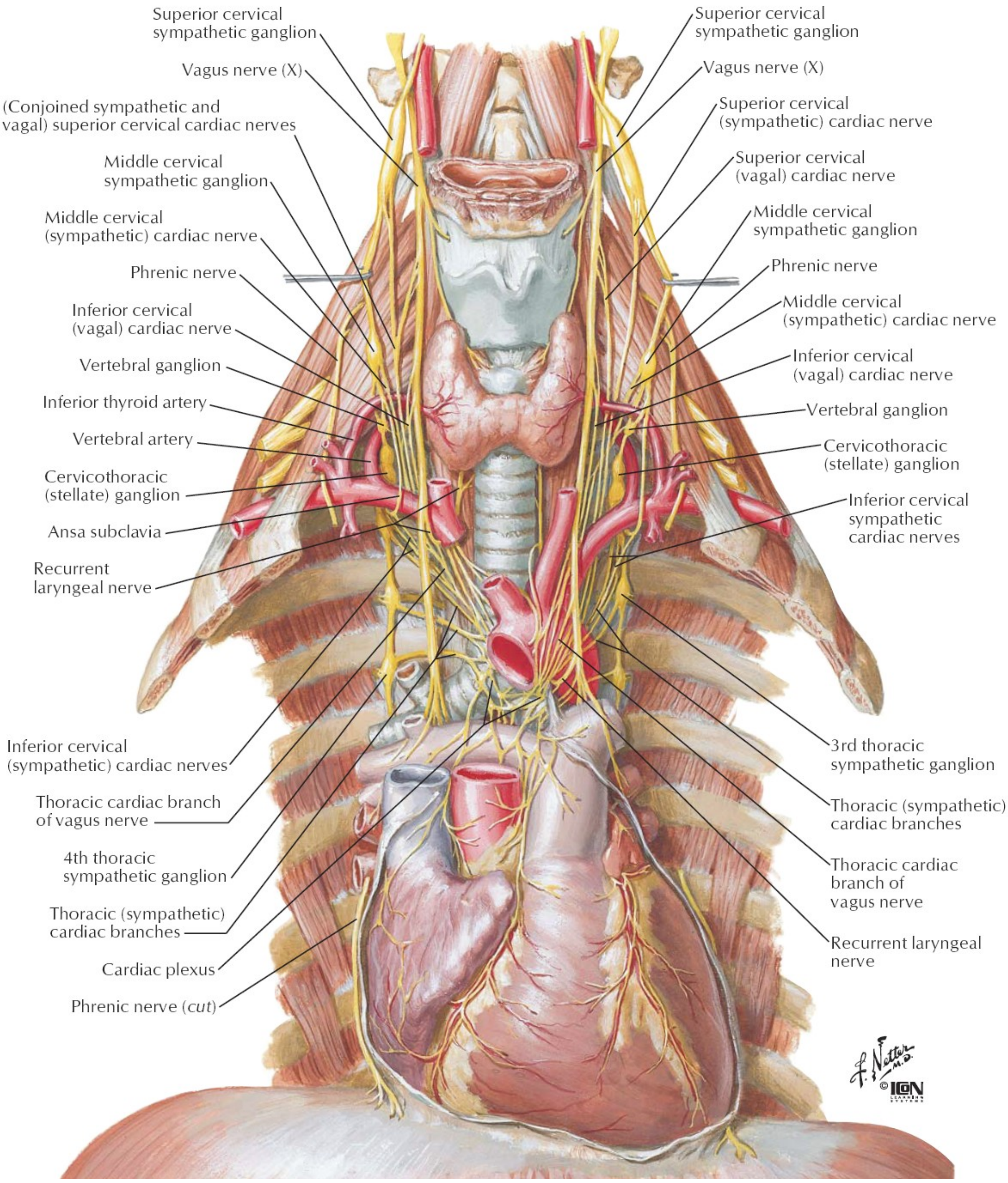
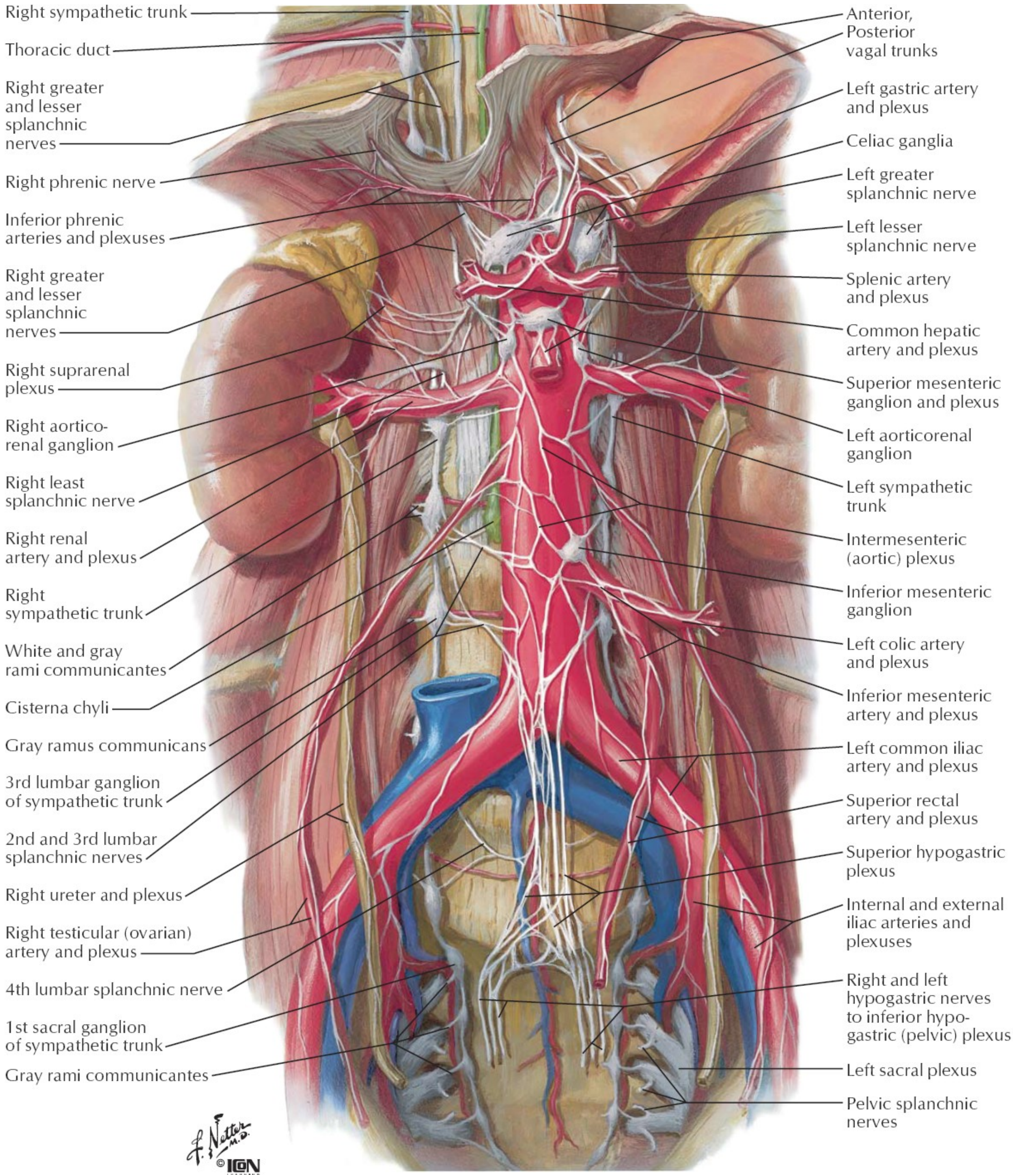
Sympathetic fibers
Presynaptic
Postsynaptic
Parasympathetic fibers
Presynaptic
Postsynaptic
Antidromic conduction


Midbrain
Pons
Medulla
Superior cervical ganglion
Sympathetic trunk (chain) ganglia
Middle cervical ganglion
Inferior cervical ganglion
T1
L2
White rami communicantes
Cardiac and pulmonary plexuses
Greater splanchnic nerve
Lesser splanchnic nerve
Celiac ganglion
Superior mesenteric ganglion
Aortic plexus on aorta
Inferior mesenteric ganglion
Lumbar splanchnic nerves
Inferior hypogastric plexus
Eye
Lacrimal gland
Nasal mucosa
Blood vessels; skin (arrector pili muscles and sweat glands)
Salivary glands
Heart
Lung
Liver and gall-bladder
Stomach
Spleen
Adrenal gland
Kidney
Small intestine
Large intestine
Rectum
Genitalia (uterus, vagina, and penis) and urinary bladder
Sympathetic division (thoracolumbar)


CN III
CN VII
CN IX
CN X
Ciliary ganglion
Eye
Lacrimal gland
Pterygopalatine ganglion
Nasal mucosa
Submandibular ganglion
Submandibular and sublingual glands
Otic ganglion
Parotid gland
Heart
Cardiac and pulmonary plexuses
Lung
Liver and gallbladder
Celiac plexus
Stomach
S_2
S_4
Pancreas
Large intestine
Pelvic splanchnic nerves
Small intestine
Inferior hypogastric plexus
Rectum
Urinary bladder and ureters
Genitalia (penis, clitoris, and vagina)



Superior cervical sympathetic ganglion
Vagus nerve (X)
(Conjoined sympathetic and vagal) superior cervical cardiac nerves
Middle cervical sympathetic ganglion
Middle cervical (sympathetic) cardiac nerve
Phrenic nerve
Inferior cervical (vagal) cardiac nerve
Vertebral ganglion
Inferior thyroid artery
Vertebral artery
Cervicothoracic (stellate) ganglion
Ansa subclavia
Recurrent laryngeal nerve
Inferior cervical (sympathetic) cardiac nerves
Thoracic cardiac branch of vagus nerve
4th thoracic sympathetic ganglion
Thoracic (sympathetic) cardiac branches
Cardiac plexus
Phrenic nerve (*cut*)
Superior cervical sympathetic ganglion
Vagus nerve (X)
Superior cervical (sympathetic) cardiac nerve
Superior cervical (vagal) cardiac nerve
Middle cervical sympathetic ganglion
Phrenic nerve
Middle cervical (sympathetic) cardiac nerve
Inferior cervical (vagal) cardiac nerve
Vertebral ganglion
Cervicothoracic (stellate) ganglion
Inferior cervical sympathetic cardiac nerves
3rd thoracic sympathetic ganglion
Thoracic (sympathetic) cardiac branches
Thoracic cardiac branch of vagus nerve
Recurrent laryngeal nerve



Right sympathetic trunk
Thoracic duct
Right greater and lesser splanchnic nerves
Right phrenic nerve
Inferior phrenic arteries and plexuses
Right greater and lesser splanchnic nerves
Right suprarenal plexus
Right aortico-renal ganglion
Right least splanchnic nerve
Right renal artery and plexus
Right sympathetic trunk
White and gray rami communicantes
Cisterna chyli
Gray ramus communicans
3rd lumbar ganglion of sympathetic trunk
2nd and 3rd lumbar splanchnic nerves
Right ureter and plexus
Right testicular (ovarian) artery and plexus
4th lumbar splanchnic nerve
1st sacral ganglion of sympathetic trunk
Gray rami communicantes
Anterior, Posterior vagal trunks
Left gastric artery and plexus
Celiac ganglia
Left greater splanchnic nerve
Left lesser splanchnic nerve
Splenic artery and plexus
Common hepatic artery and plexus
Superior mesenteric ganglion and plexus
Left aorticorenal ganglion
Left sympathetic trunk
Intermesenteric (aortic) plexus
Inferior mesenteric ganglion
Left colic artery and plexus
Inferior mesenteric artery and plexus
Left common iliac artery and plexus
Superior rectal artery and plexus
Superior hypogastric plexus
Internal and external iliac arteries and plexuses
Right and left hypogastric nerves to inferior hypogastric (pelvic) plexus
Left sacral plexus
Pelvic splanchnic nerves
F. Netter M.D.
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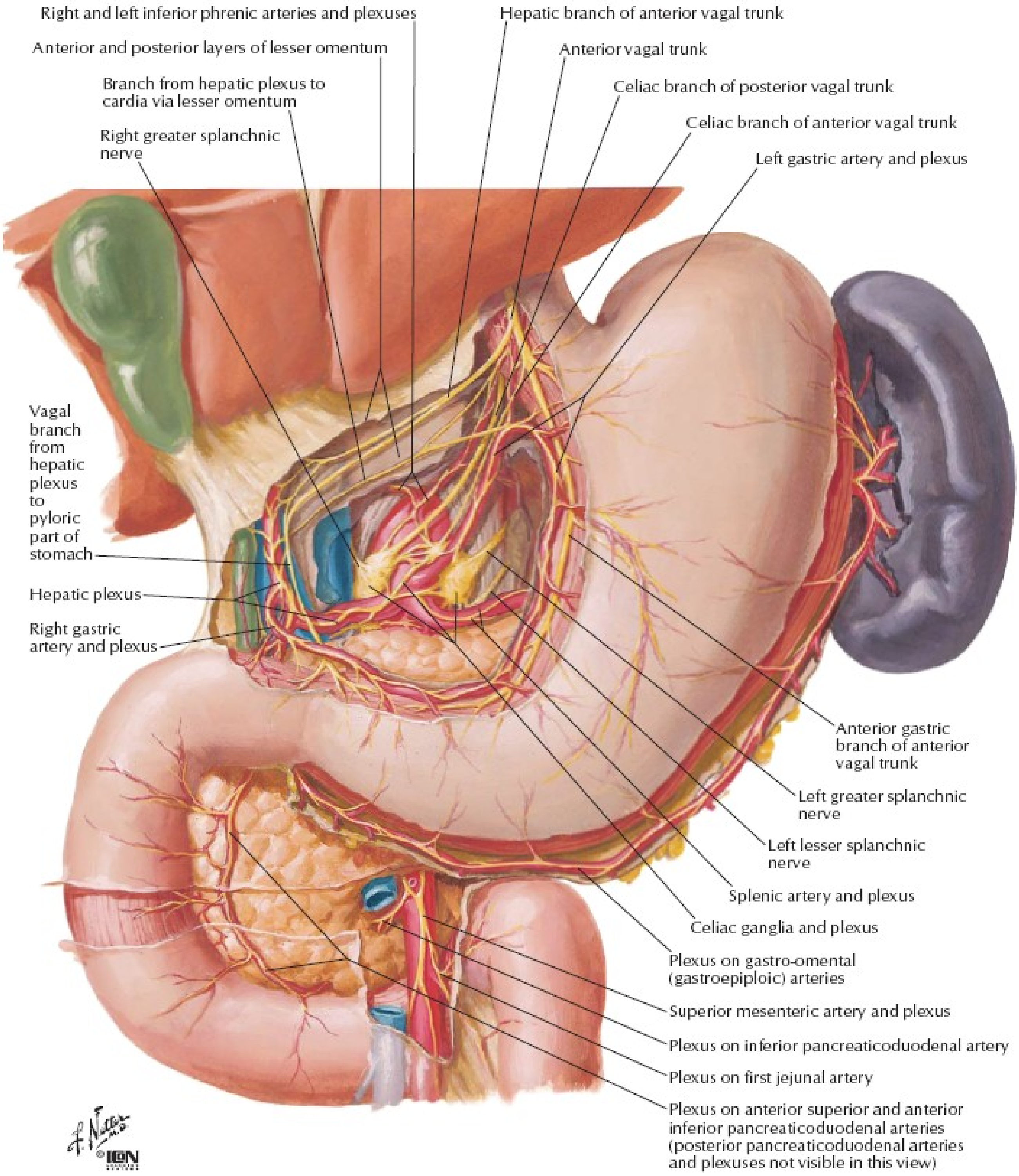
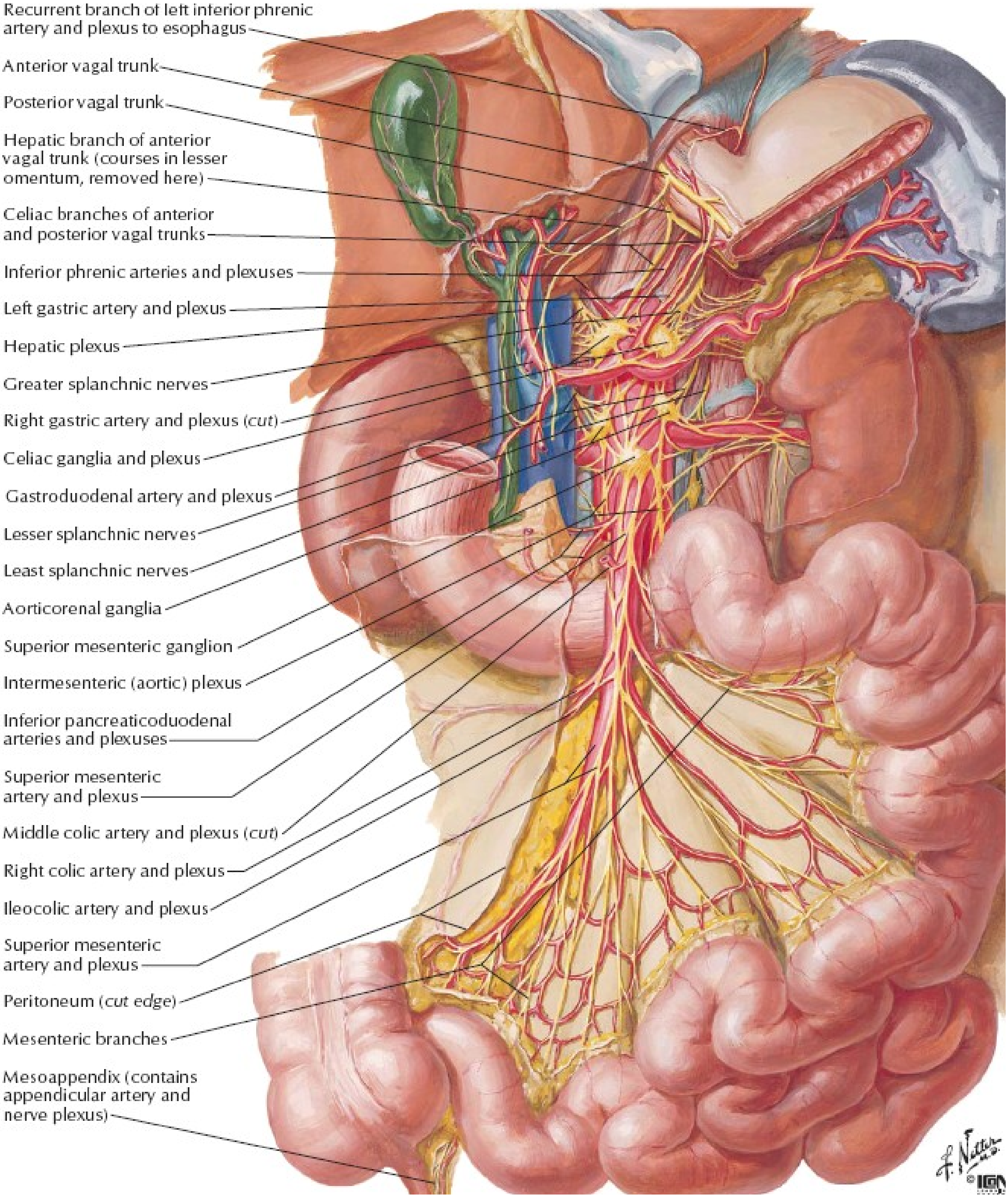
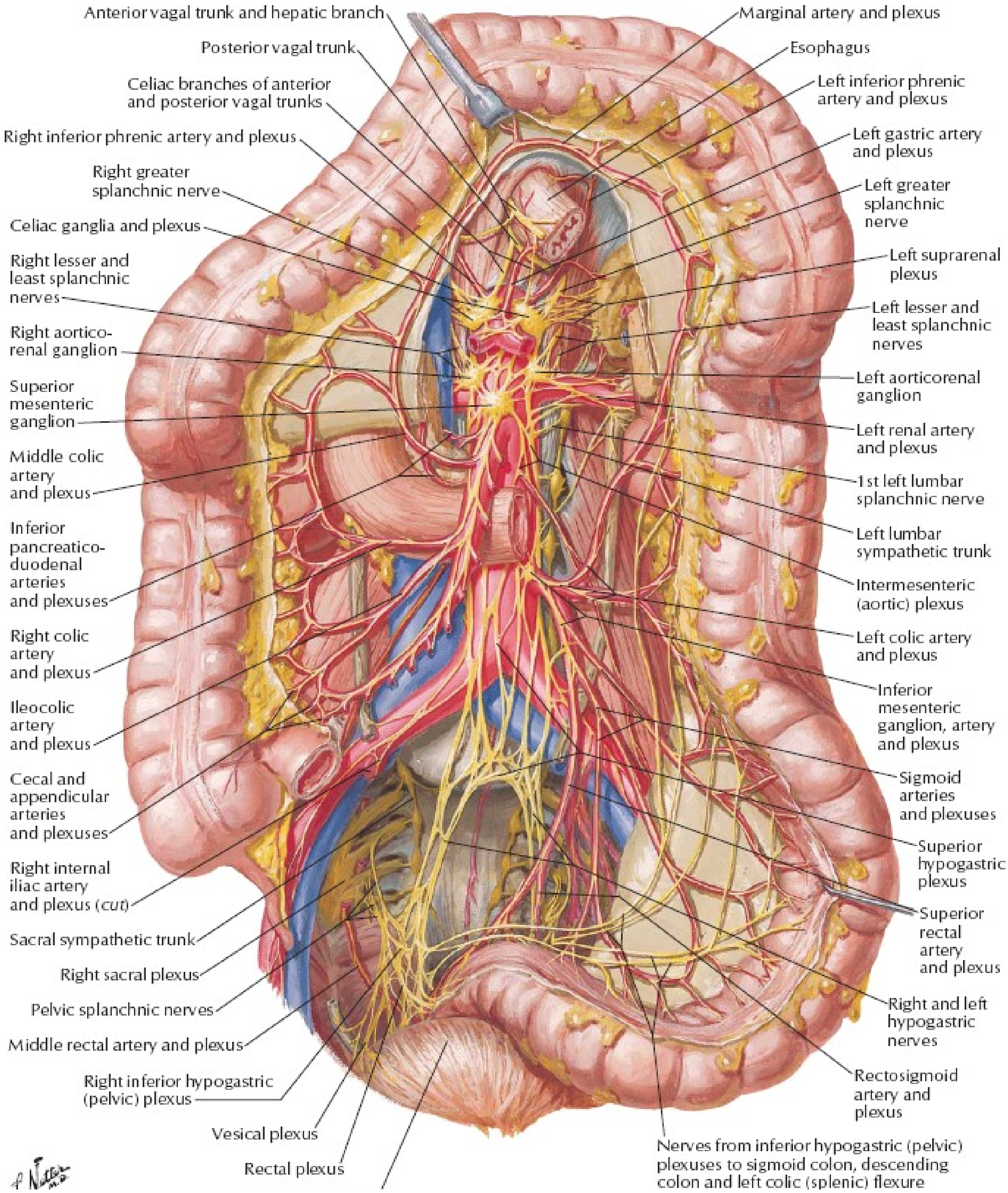
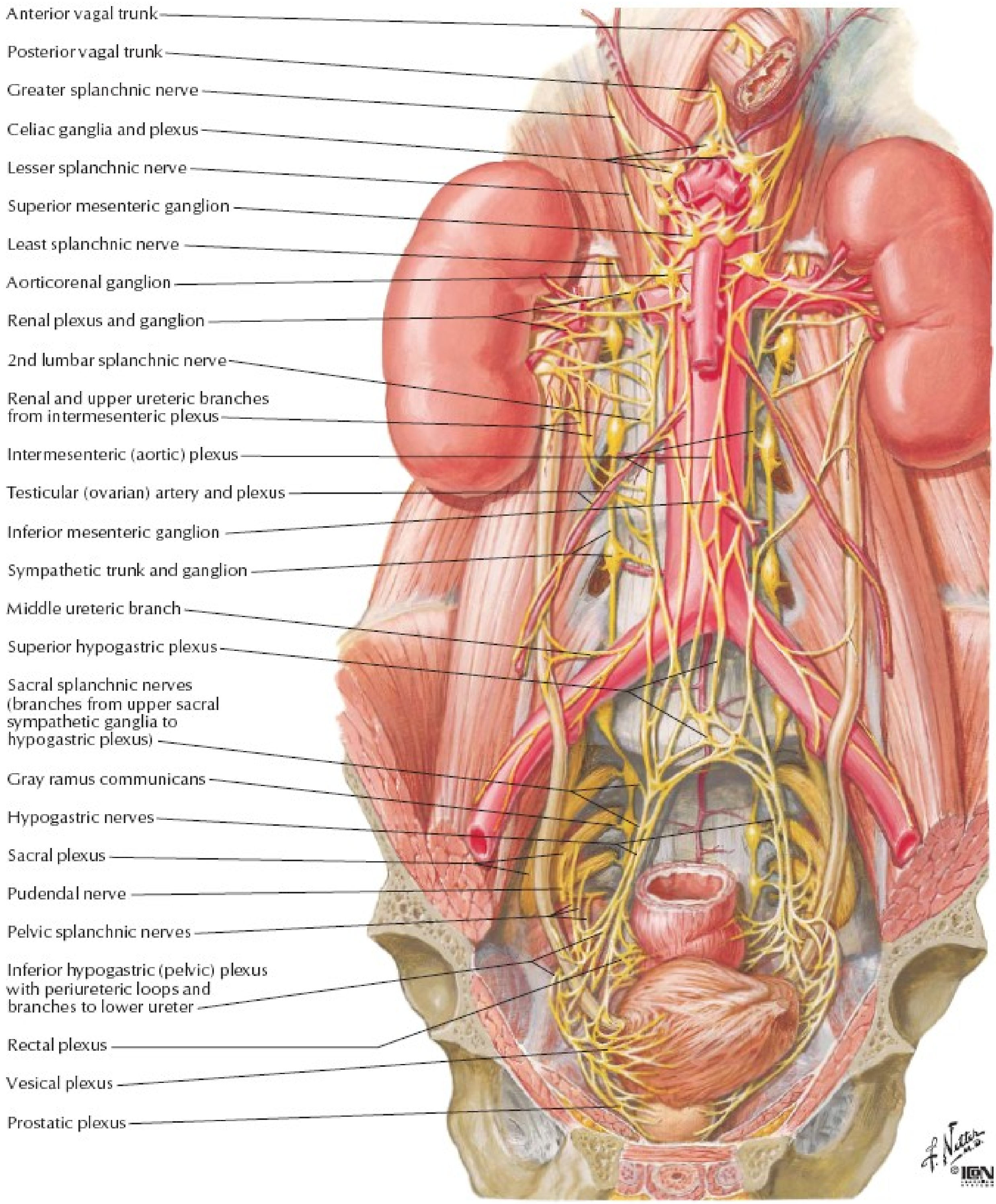

Right and left inferior phrenic arteries and plexuses
Anterior and posterior layers of lesser omentum
Branch from hepatic plexus to cardia via lesser omentum
Right greater splanchnic nerve
Hepatic branch of anterior vagal trunk
Anterior vagal trunk
Celiac branch of posterior vagal trunk
Celiac branch of anterior vagal trunk
Left gastric artery and plexus
Vagal branch from hepatic plexus to pyloric part of stomach
Hepatic plexus
Right gastric artery and plexus
Anterior gastric branch of anterior vagal trunk
Left greater splanchnic nerve
Left lesser splanchnic nerve
Splenic artery and plexus
Celiac ganglia and plexus
Plexus on gastro-omental (gastroepiploic) arteries
Superior mesenteric artery and plexus
Plexus on inferior pancreaticoduodenal artery
Plexus on first jejunal artery
Plexus on anterior superior and anterior inferior pancreaticoduodenal arteries (posterior pancreaticoduodenal arteries and plexuses not visible in this view)


Recurrent branch of left inferior phrenic artery and plexus to esophagus
Anterior vagal trunk
Posterior vagal trunk
Hepatic branch of anterior vagal trunk (courses in lesser omentum, removed here)
Celiac branches of anterior and posterior vagal trunks
Inferior phrenic arteries and plexuses
Left gastric artery and plexus
Hepatic plexus
Greater splanchnic nerves
Right gastric artery and plexus (cut)
Celiac ganglia and plexus
Gastroduodenal artery and plexus
Lesser splanchnic nerves
Least splanchnic nerves
Aorticorenal ganglia
Superior mesenteric ganglion
Intermesenteric (aortic) plexus
Inferior pancreaticoduodenal arteries and plexuses
Superior mesenteric artery and plexus
Middle colic artery and plexus (cut)
Right colic artery and plexus
Ileocolic artery and plexus
Superior mesenteric artery and plexus
Peritoneum (cut edge)
Mesenteric branches
Mesoappendix (contains appendicular artery and nerve plexus)


Anterior vagal trunk and hepatic branch
Posterior vagal trunk
Celiac branches of anterior and posterior vagal trunks
Right inferior phrenic artery and plexus
Right greater splanchnic nerve
Celiac ganglia and plexus
Right lesser and least splanchnic nerves
Right aortico-renal ganglion
Superior mesenteric ganglion
Middle colic artery and plexus
Inferior pancreatico-duodenal arteries and plexuses
Right colic artery and plexus
Ileocolic artery and plexus
Cecal and appendicular arteries and plexuses
Right internal iliac artery and plexus (cut)
Sacral sympathetic trunk
Right sacral plexus
Pelvic splanchnic nerves
Middle rectal artery and plexus
Right inferior hypogastric (pelvic) plexus
Vesical plexus
Rectal plexus
Marginal artery and plexus
Esophagus
Left inferior phrenic artery and plexus
Left gastric artery and plexus
Left greater splanchnic nerve
Left suprarenal plexus
Left lesser and least splanchnic nerves
Left aorticorenal ganglion
Left renal artery and plexus
1st left lumbar splanchnic nerve
Left lumbar sympathetic trunk
Intermesenteric (aortic) plexus
Left colic artery and plexus
Inferior mesenteric ganglion, artery and plexus
Sigmoid arteries and plexuses
Superior hypogastric plexus
Superior rectal artery and plexus
Right and left hypogastric nerves
Rectosigmoid artery and plexus
Nerves from inferior hypogastric (pelvic) plexuses to sigmoid colon, descending colon and left colic (splenic) flexure



Anterior vagal trunk
Posterior vagal trunk
Greater splanchnic nerve
Celiac ganglia and plexus
Lesser splanchnic nerve
Superior mesenteric ganglion
Least splanchnic nerve
Aorticorenal ganglion
Renal plexus and ganglion
2nd lumbar splanchnic nerve
Renal and upper ureteric branches from intermesenteric plexus
Intermesenteric (aortic) plexus
Testicular (ovarian) artery and plexus
Inferior mesenteric ganglion
Sympathetic trunk and ganglion
Middle ureteric branch
Superior hypogastric plexus
Sacral splanchnic nerves (branches from upper sacral sympathetic ganglia to hypogastric plexus)
Gray ramus communicans
Hypogastric nerves
Sacral plexus
Pudendal nerve
Pelvic splanchnic nerves
Inferior hypogastric (pelvic) plexus with periureteric loops and branches to lower ureter
Rectal plexus
Vesical plexus
Prostatic plexus
F. Netter
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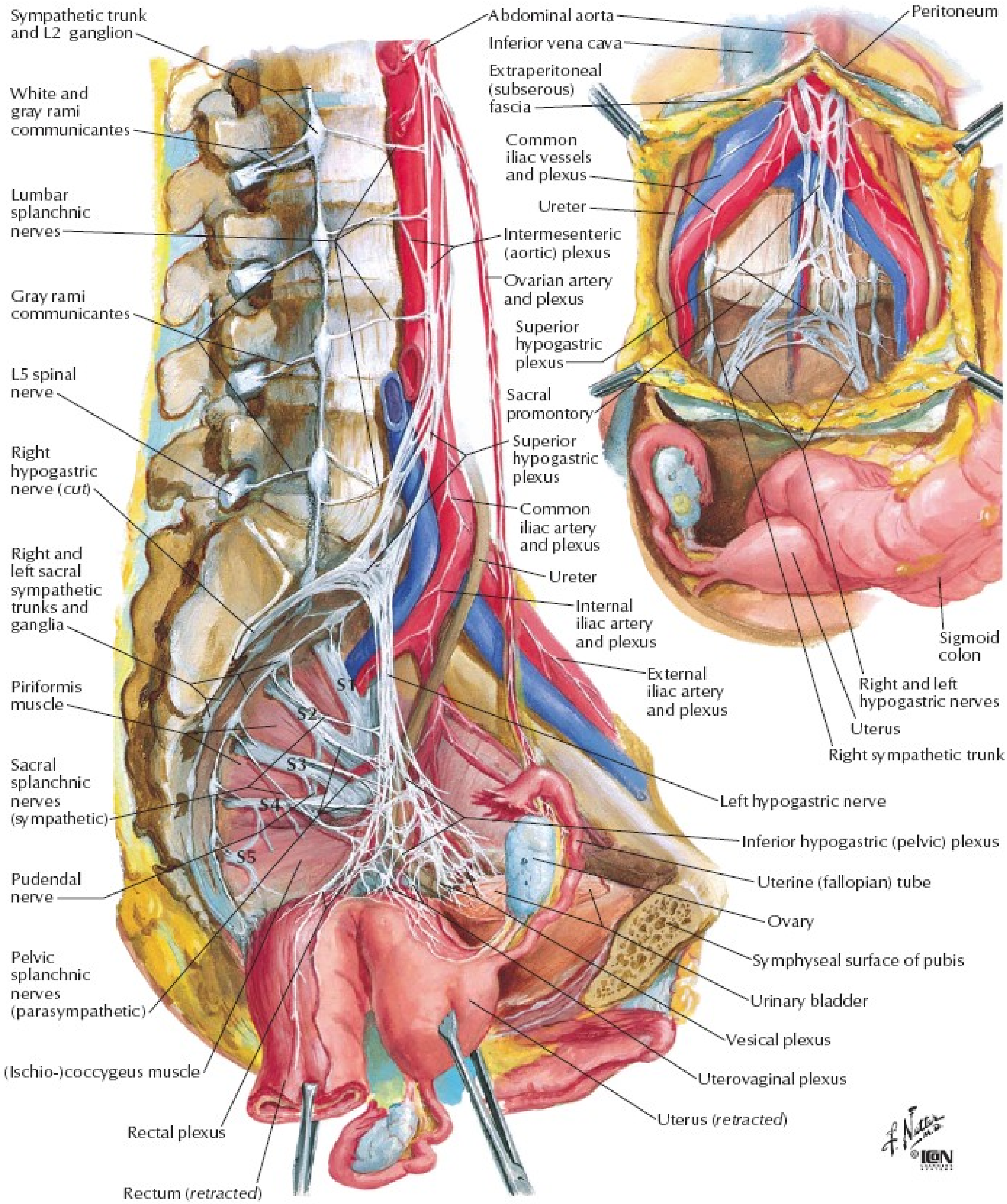
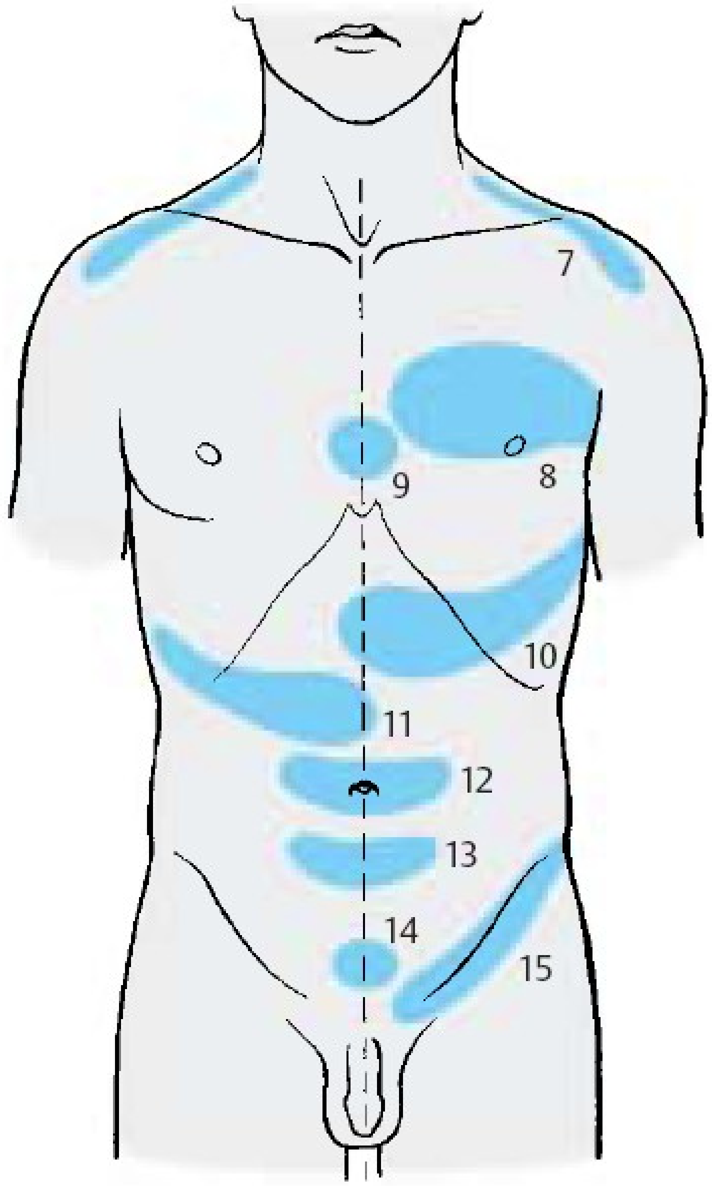

Sympathetic trunk and L2 ganglion
White and gray rami communicantes
Lumbar splanchnic nerves
Gray rami communicantes
L5 spinal nerve
Right hypogastric nerve (cut)
Right and left sacral sympathetic trunks and ganglia
Piriformis muscle
Sacral splanchnic nerves (sympathetic)
Pudendal nerve
Pelvic splanchnic nerves (parasympathetic)
(Ischio-)coccygeus muscle
Rectal plexus
Rectum (retracted)
S1
S2
S3
S4
S5
Abdominal aorta
Inferior vena cava
Extraperitoneal (subserous) fascia
Common iliac vessels and plexus
Ureter
Intermesenteric (aortic) plexus
Ovarian artery and plexus
Superior hypogastric plexus
Sacral promontory
Superior hypogastric plexus
Common iliac artery and plexus
Ureter
Internal iliac artery and plexus
External iliac artery and plexus
Peritoneum
Sigmoid colon
Right and left hypogastric nerves
Uterus
Right sympathetic trunk
Left hypogastric nerve
Inferior hypogastric (pelvic) plexus
Uterine (fallopian) tube
Ovary
Symphyseal surface of pubis
Urinary bladder
Vesical plexus
Uterovaginal plexus
Uterus (retracted)

Zaharin - Head’s zones



In specific skin regions (***zones of hyperalgesia***), disease of an organ may give rise to pain or hypersensitivity, with each organ being represented in a specific zone: diaphragm (**7**) (C4), heart (**8**) (T3/4), esophagus (**9**) (T4/5), stomach (**10**) (T8), liver and gallbladder (**11**) (T8 – 11), small intestine (**12**) (T10), large intestine (**13**) (T11), urinary bladder (**14**) (T11–L1), kidneys and testes (**15**) (T10–L1).

These zones are of practical importance in the diagnosis.