Lesson №26

EVOLUTION OF ORGAN SYSTEMS (PART II)

Phylogenesis of the circulatory system of chordates

The circulatory system originates from mesoderm.

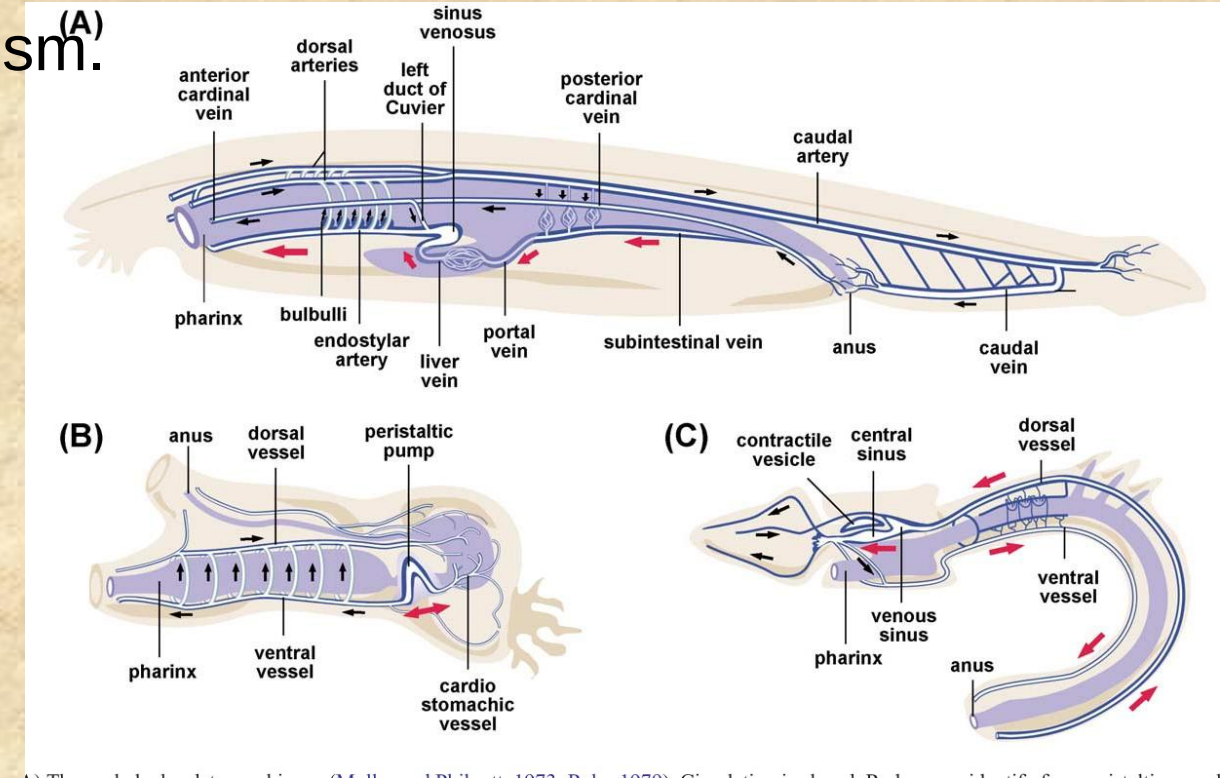
Basic directions of evolution:

1. Appearance and differentiation of the heart (change of two-chambered heart into the four-chambered one).

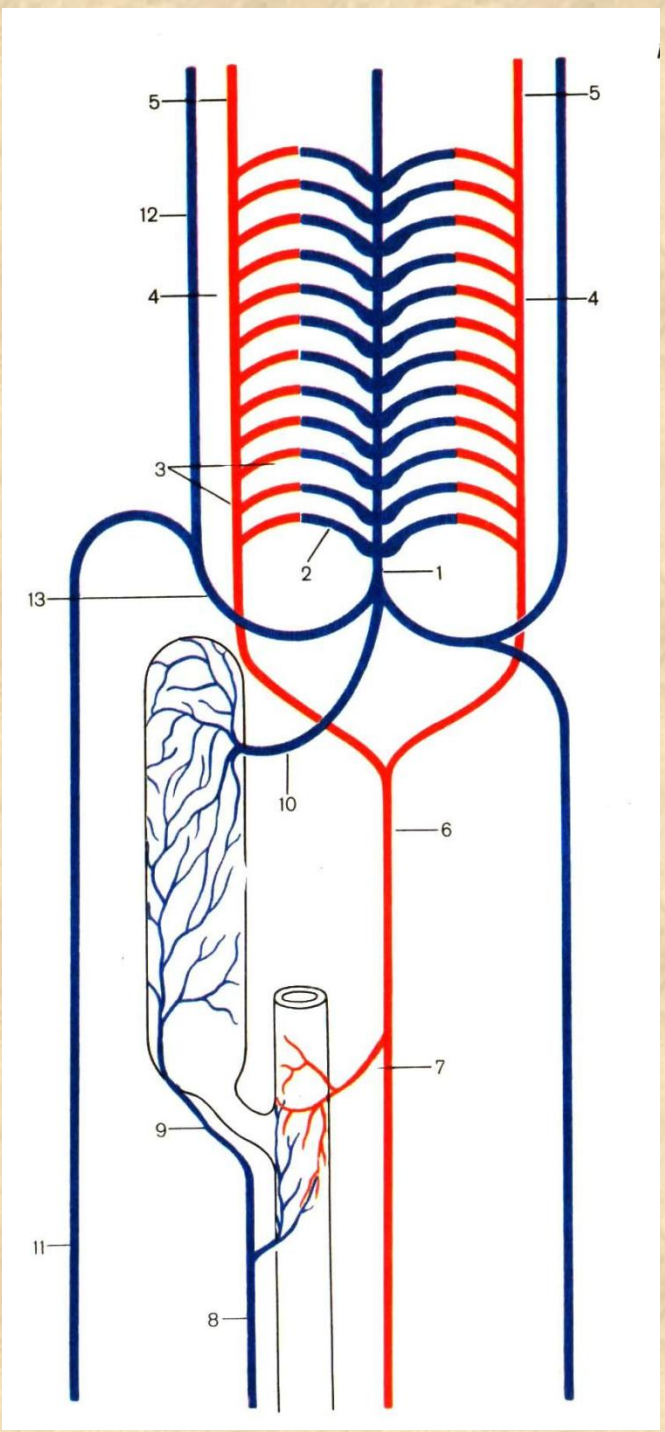
2. Appearance of the 2nd (pulmonary) circulation and a complete separation of the venous and arterial blood.

3. Transformation of branchial arteries (arterial arches) and differentiation of vessels following from the heart.

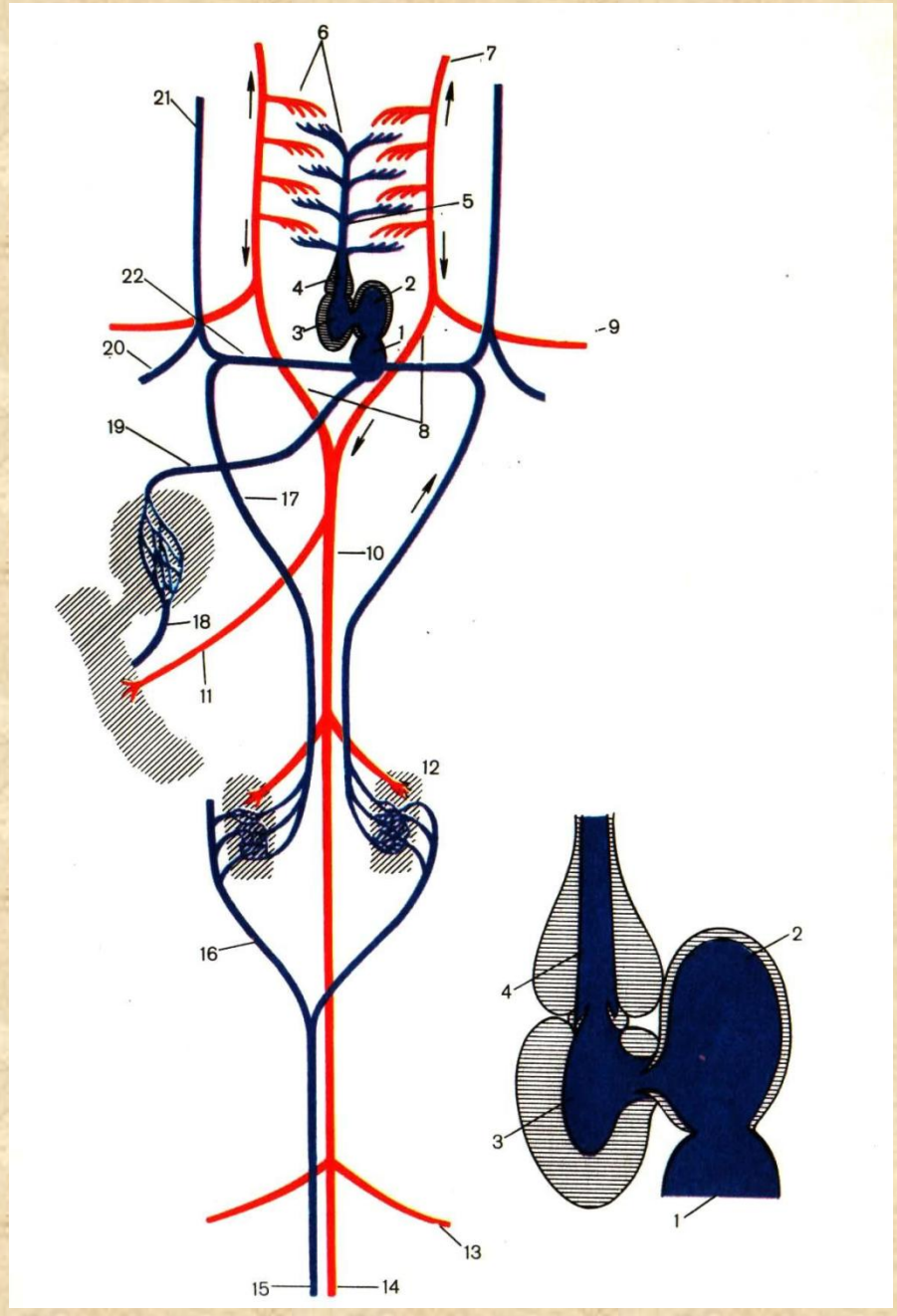
A lancelet has one circulation. The abdominal aorta (1) carrying venous blood comes into afferent branchial arteries (2). Their number corresponds to the number of branchial arches (up to 150 pairs), where it gets enriched with oxygen. Through efferent branchial arteries (3) the blood comes to carotid arteries (5) (they carry blood to the anterior region of the body) and into a dorsal aorta (6) that branches into multiple arteries, and carries the blood throughout the organism.



After gas exchange the venous blood accumulates in paired anterior (12) and posterior (11) cardial veins located symmetrically. The anterior and posterior cardial veins join together into the Cuvier's ducts (13). They empty into the abdominal aorta (1). Portal system (9) is formed near the hepatic cecum. Blood from there passes through the hepatic vein (10) into the abdominal aorta (1).

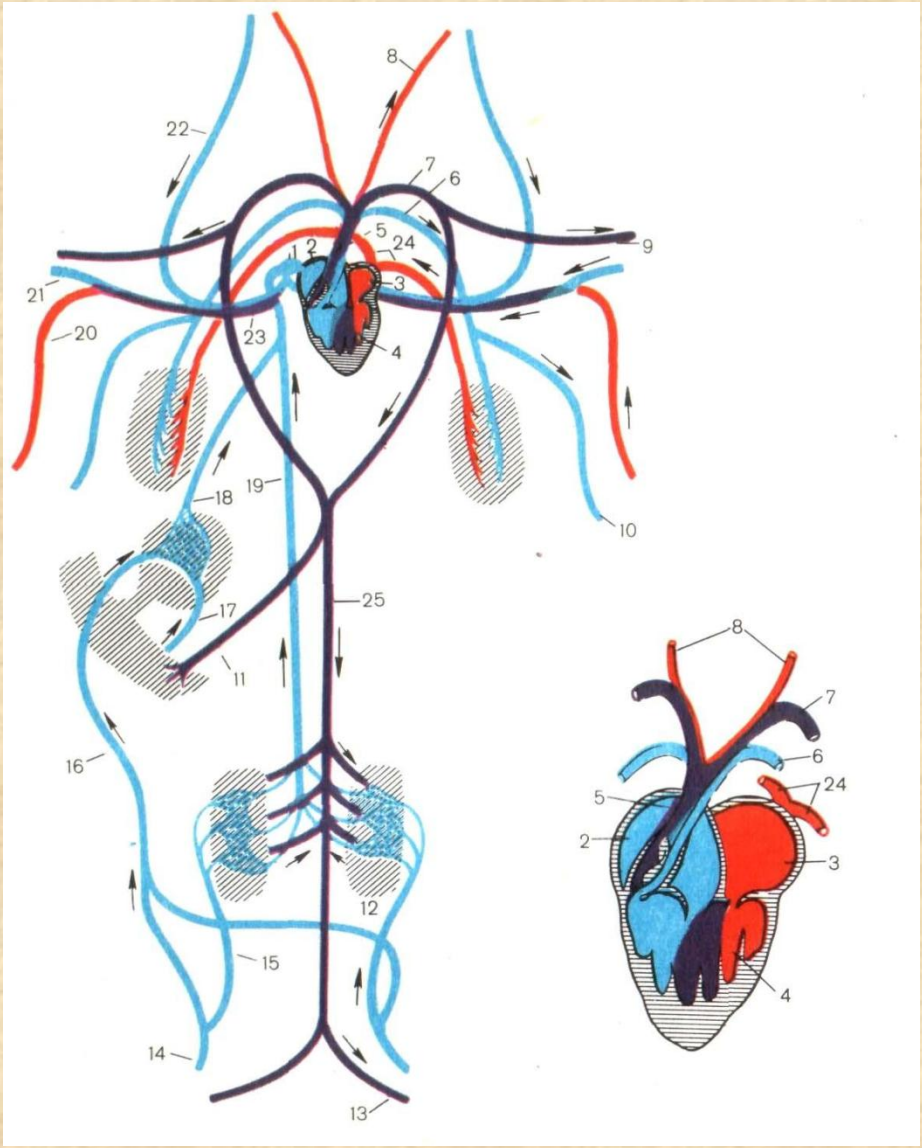


Fishes have one circulation. The heart is located beneath the mandible and consists of two chambers (an atrium (2) and a ventricle (3)) filled with venous blood. A venous sinus (1) borders upon the atrium; an arterial cone (4) follows by the ventricle and passes into the abdominal aorta (5). Anlages of 5th–7th pairs of branchial arteries are formed during embryogenesis but then the 1st, 2nd and 7th are reduced, and only the 3rd–6th pairs continue functioning (6). Otherwise, the circulatory system is similar to the lancelet system.



Due to appearance of lungs, 2nd circulation develops in **amphibians**. The heart consists of two atria (2,3) and one ventricle (4). A venous sinus borders upon the right atrium (1), an arterial cone (5) follows by the ventricle.

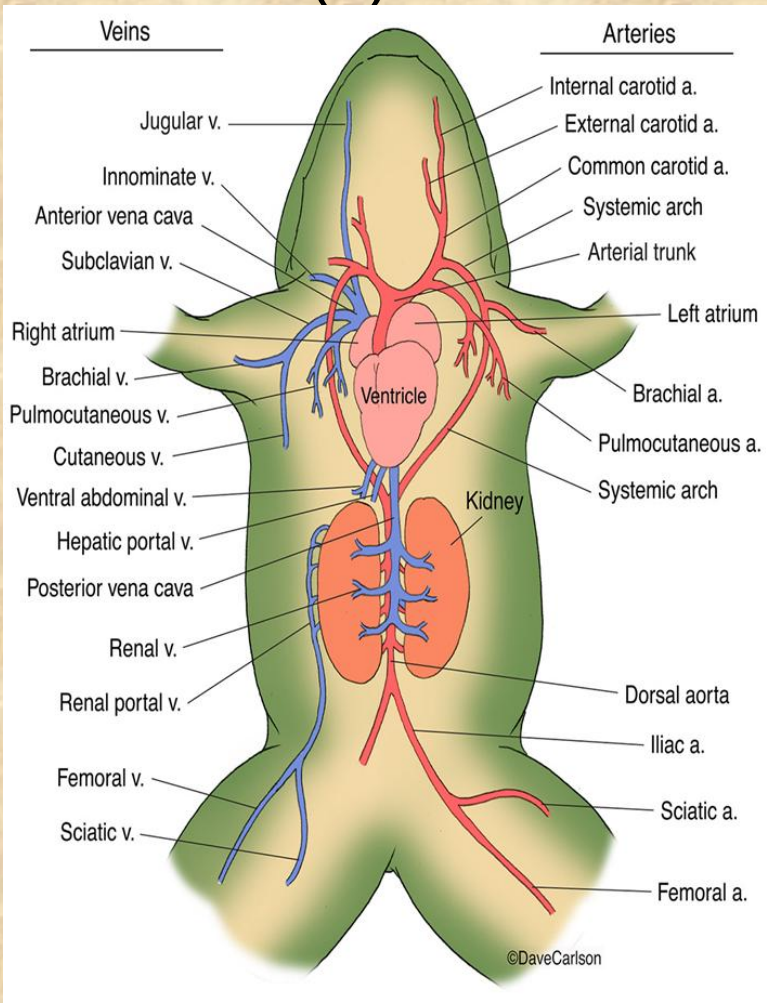
The atria open into the ventricle with one aperture. Venous and arterial blood come from the right and left atria. The blood in the right part of the ventricle is venous, mixed in the center and arterial in the left part.



The blood is distributed into 3 pairs of vessels through the arterial cone: venous blood goes to the skin and lungs through the pulmocutaneous arteries (6); mixed blood goes to all organs through aortal arches (7); arterial blood goes to the brain through carotid arteries (8).

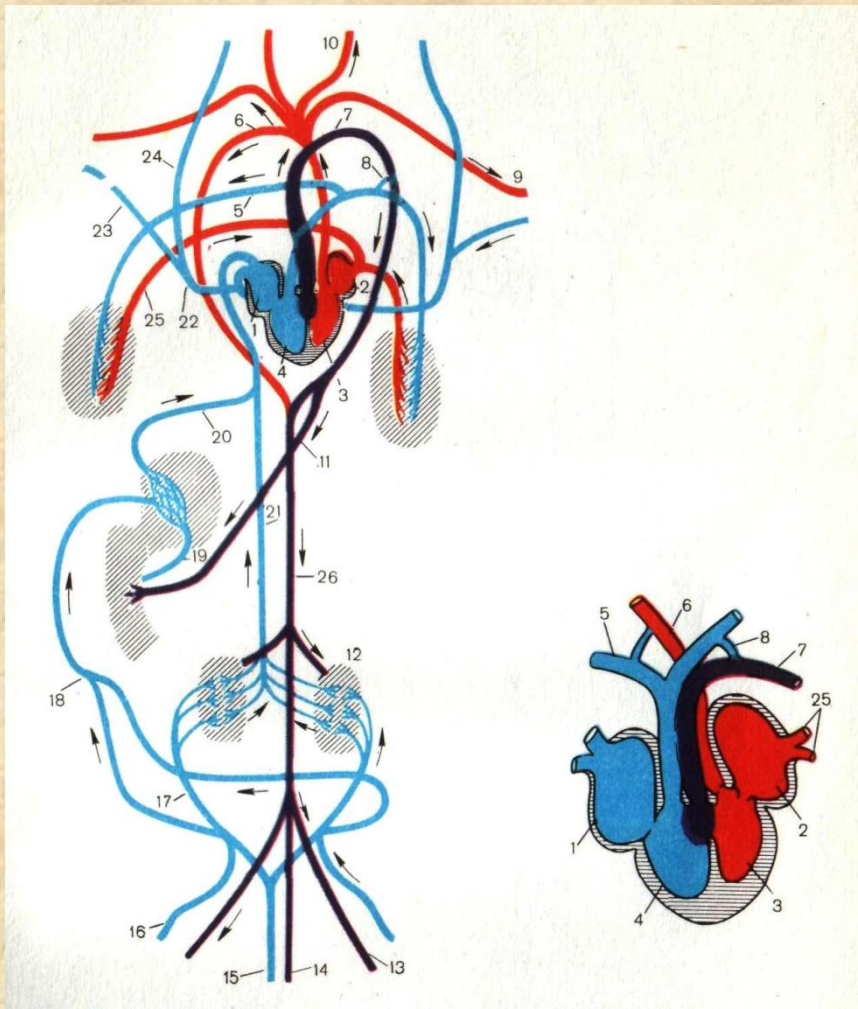
Anlages of 6–7 pairs of branchial arteries are formed in embryogenesis and then the 1st, 2nd, 5th and 7th are reduced.

The 3rd one transforms into carotid arteries, the 4th one form arches of the aorta, the 6th — pulmocutaneous arteries

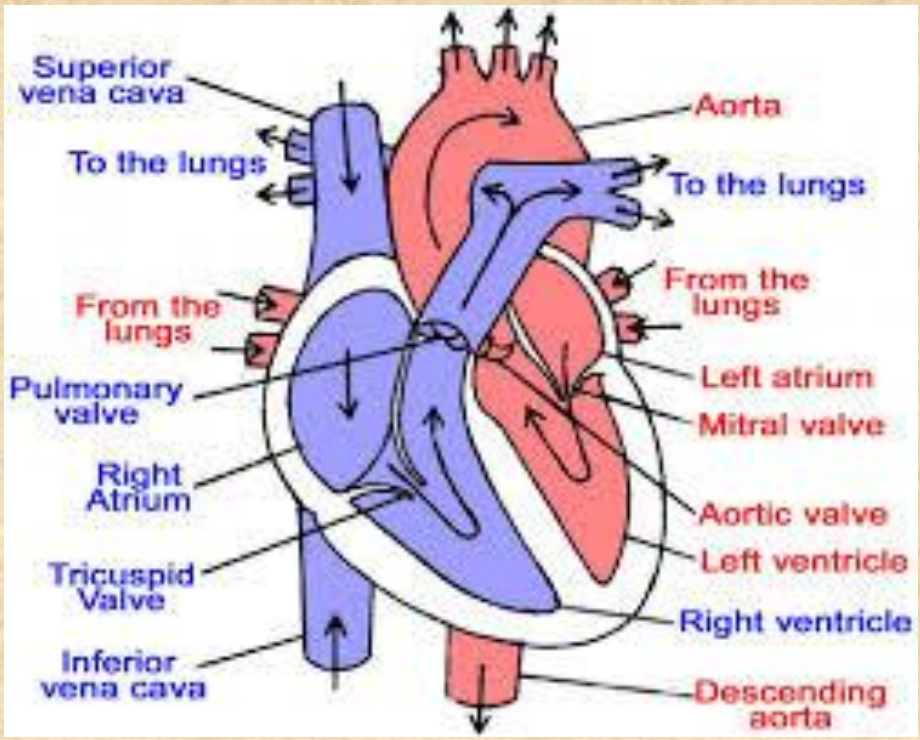


In **reptiles** the heart consists of 3 chambers, an incomplete septum appears in the ventricle. The pulmonary artery (5) springs from the right part of the ventricle, it carries venous blood to the lungs; from the left part springs the right arch of the aorta (6) that carries arterial blood to the brain and forelimbs.

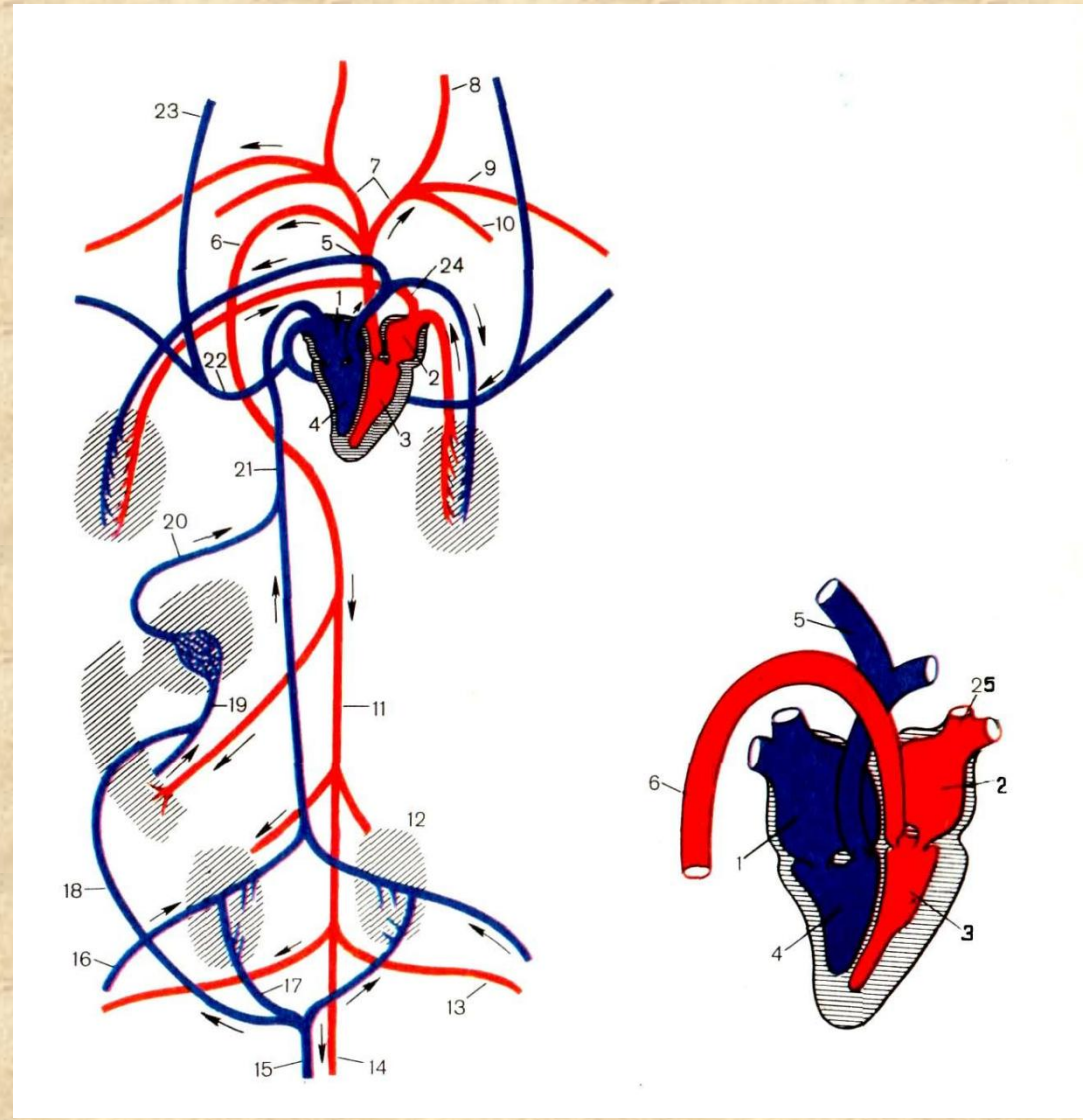
The left arch of the aorta (7) springs from the center of the ventricle, it carries mixed blood. Behind the heart 2 arches of the aorta fuse into one vessel and carry mixed blood to all organs. Anlages of 6 pairs of branchial arteries are formed. They transform into the same vessels as in amphibians (the 6th pair — into pulmonary arteries).



In **mammals** the heart is completely divides into the left and right halves to ultimately separate arterial and venous blood. The right heart contains venous blood while the left one is filled with arterial blood. The pulmonary circulation starts from the right ventricle with pulmonary arteries and terminates in the left atrium with pulmonary veins. The systemic circulation starts from the left ventricle with a left arch of the aorta and ends in the right atrium with vena cava.

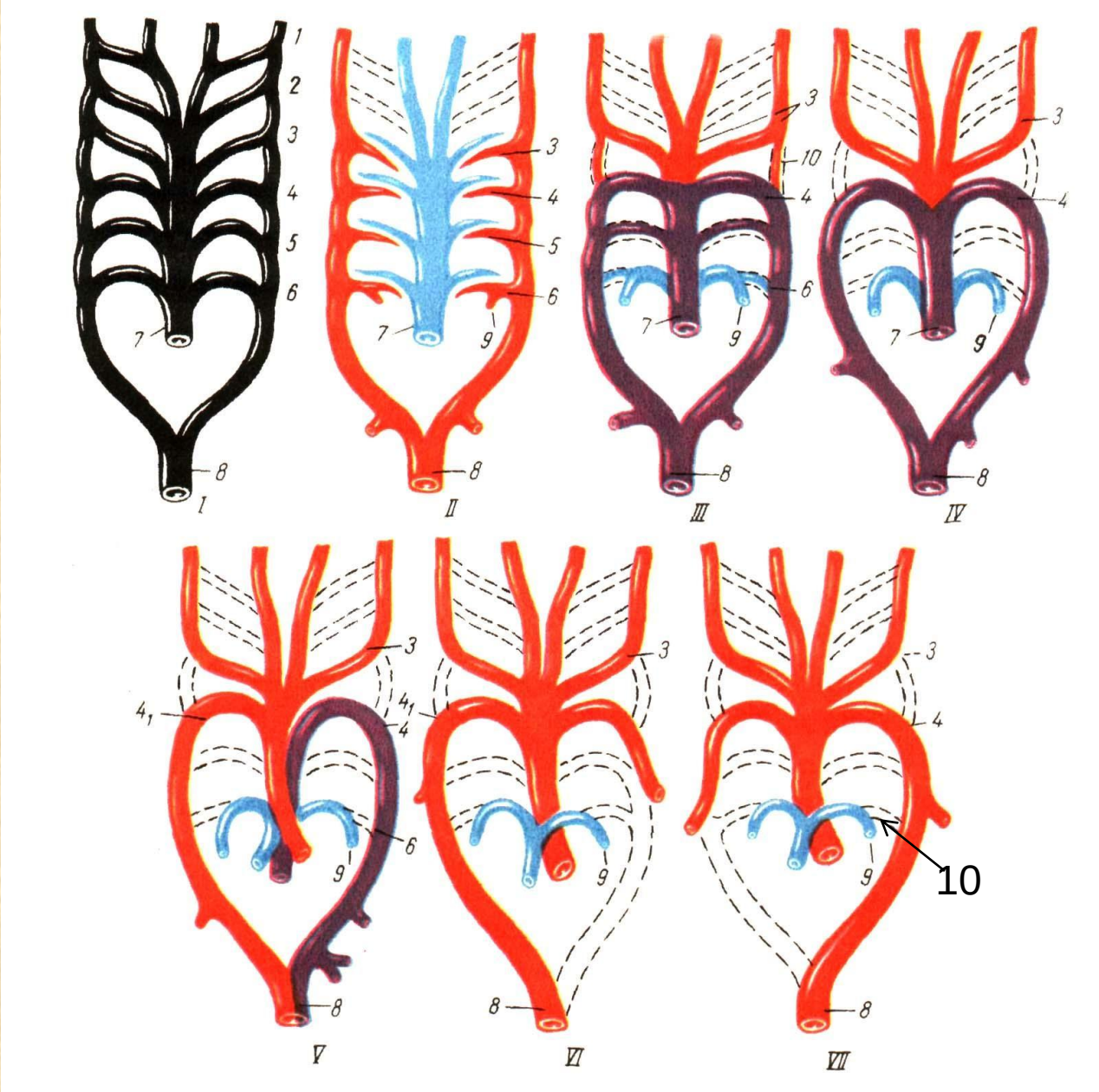


Anlages of 6 pairs of branchial arteries are formed in embryogenesis, then in the 1st and 2nd pairs are reduced; the 3rd pair forms carotid arteries; the right one of 4th pair is reduced while the left one forms an arch of the aorta; the 5th pair is reduced; the 6th pair transforms into pulmonary arteries.



Development of arterial arches in vertebrate animals

I – anlage of a vertebrate
II – fish
III – tailed amphibian
IV – anura amphibian
V – reptile
VI – bird
VII – mammal
1-6 – arterial (brachial) arches
7 – abdominal aorta
8 – dorsal aorta
9 – pulmonary arteries
10 – Botallo duct



Ontophylogenetic etiology of cardiovascular malformations: two-chamber and three-chamber heart, cervical ectopia of the heart, ventricular septal defect, open Botallo duct, underdevelopment of aortopulmonary septum (incomplete separation of the arterial trunk into an aorta and a pulmonary trunk), transposition of the great vessels, preservation of both aortal arches, reduction of the left aortic arch and preservation of the right, persistence of the two upper hollow veins, underdevelopment of the inferior vena cava.

Phylogenesis of the excretory system of chordates

The excretory system originates from mesoderm. It is represented with nephridia in lancelets, and by kidneys in vertebrates.

Basic directions of evolution:

1. Substitution of nephridia (lancelet) with kidneys (vertebrates).

2. Transformation of a pronephros (head kidney) into a mesonephros (mesonephric kidney) and ultimatly metanephros (pelvic kidney) by increasing the number of nephrons and convergence of the nephrons and blood capillaries, elongation of nephron tubules.

The lancelet has 100–150 pairs of nephridia. They are short tubules that have one end open into a coelom, and the other one — into a peribranchial cavity. A glomerule of capillaries is situated in the coelom wall near tubules.

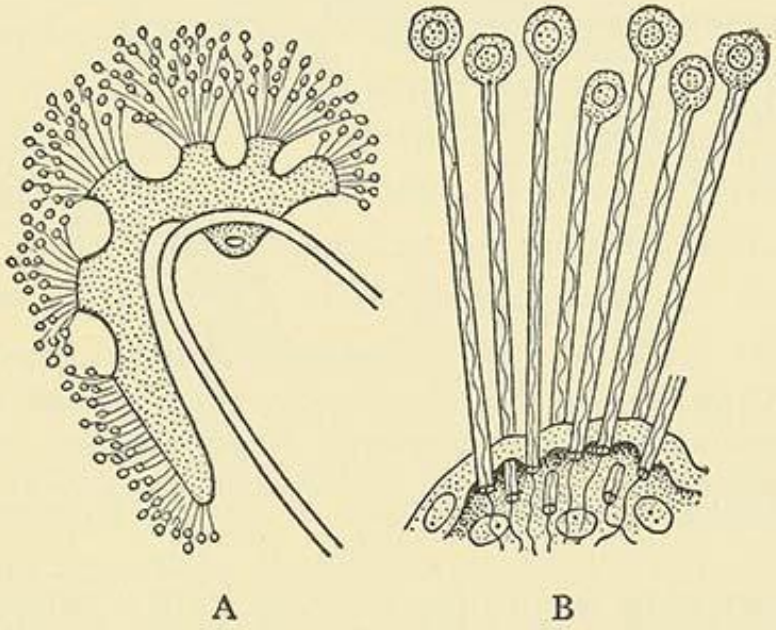


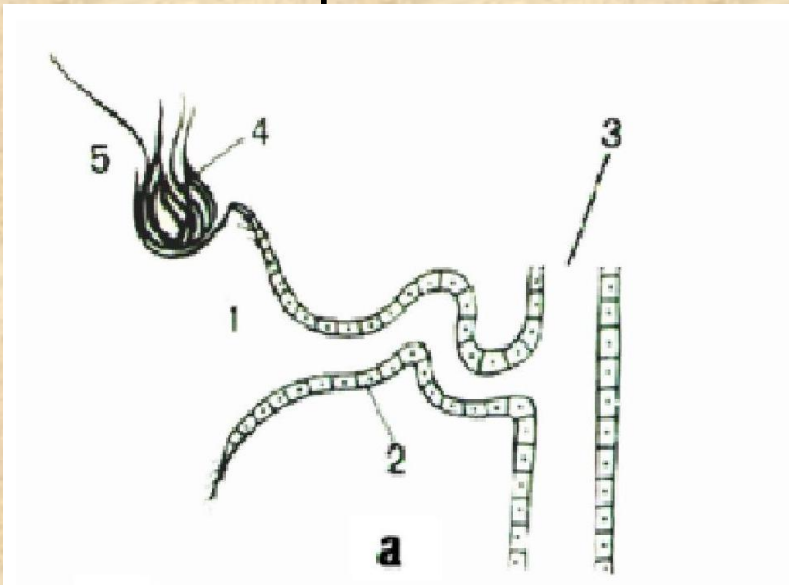
Fig. 372. Excretory tubules of amphioxus. A, a single protonephridium showing several processes, which lie in the coelom, and the single opening, which empties into the atrial cavity; B, one nephridial process enlarged to show the group of flame-cell-like solenocytes, each with a collar and flagellum. (From Newman, *The Phylum Chordata*, copyright 1939, by permission of The Macmillan Company, publishers. Modified from Boveri and Goodrich.)

In phylogenesis of vertebrates 3 generations of kidneys successively change each other: *pronephros, mesonephros, metanephros*.

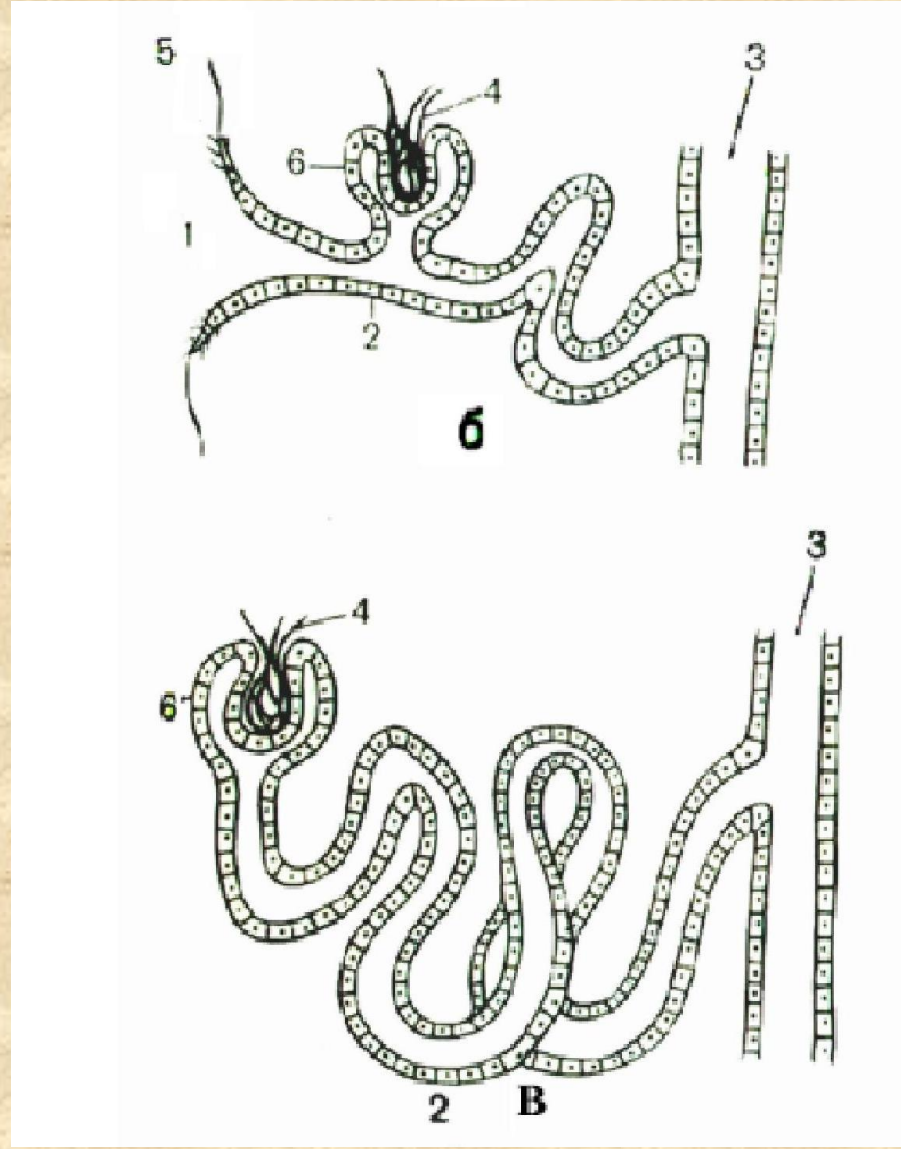
A nephron is a basic structural and functional unit of an excretory organ.

The pronephros (in larvae of fishes and amphibians) has 6–12 nephrons. The nephron consists of a funnel (nephrostome) and a short tubule. Nephrostomes open into the coelom and tubules into the ureter of the kidney. The glomerulus is located in the coelom wall near nephrostomes.

Dissimilation products pass from the blood into the coelom, then through the nephrostome into the tubule, and then into the ureter of the pronephros (pronephric duct). The ureter opens into the cloaca.

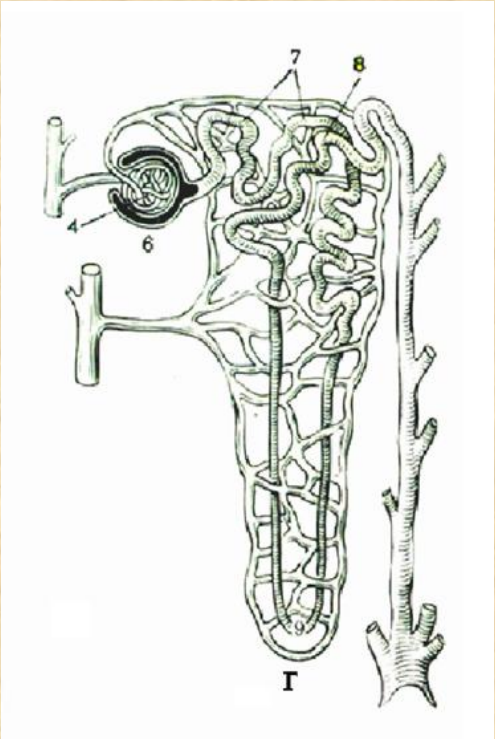


The mesonephros (mature fishes and amphibians) contain approximately 100 nephrons. Some glomeruli have an outgrowth of tubule wall in shape of two-walled capsule. Part of the nephron has nephrostomes, part of the nephron does not. Dissimilation products are removed from the blood in two ways: from the nephrostome into the tubule or from the glomerulus into the tubule.



Amniotes (higher vertebrates) have metanephros. It contains about 1 million nephrons. There is no nephrostome, the wall of the tubule completely envelopes the glomerulus (renal corpuscle consisting of a Shumlyansky–Bowman capsule and glomerulus are formed, then the tubule is differentiated into a descending part, the Henle loop and an ascending part. Removal of dissimilation products from the blood occurs directly into a tubule.

Filtration of blood plasma occurs in the glomerulus while tubules perform reabsorption of water, amino acids and glucose from primary urine. The dilation of the distal part of the ureter forms a urinary bladder.

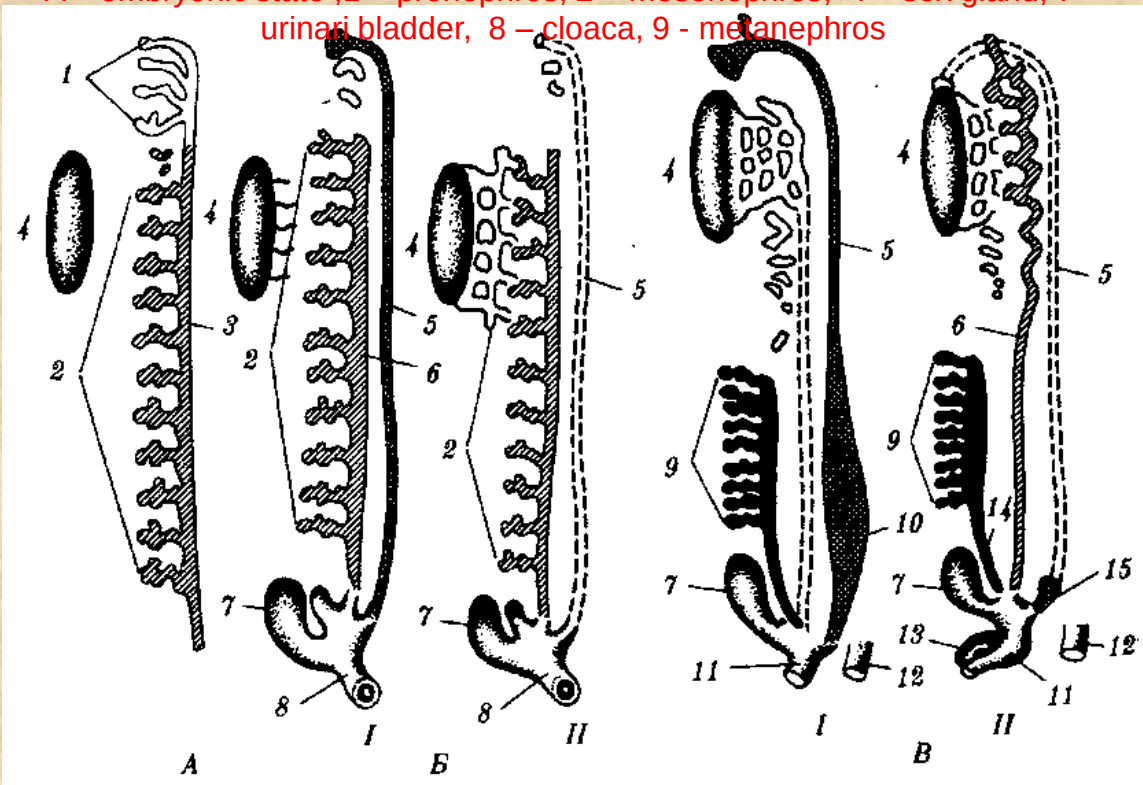


During embryonic development of the urinary system, the pronephric ducts (3) splits longitudinally into Muller ducts (5) and Wolffian ducts (6). In males of lower vertebrates (fishes and amphibians) (Б II) the Muller duct atrophies but in females (Б I) it is transformed into an oviduct (5). The Wolffian canal transforms into a ureter (6) in females or it functions as both the ureter and seminal duct in males.

In **Amniotes** males (В II) the Muller duct atrophies, the Wolffian canal fort he main length serves as seminal duct (6), and in the caudal part it serves as the ureter of the metanephros (14). For internal fertilization, a copulative organ (13) is formed from the caudal parts of Wolffian canals.

In **Amniotes** females (В I) Wolffian canal is reduced over the main length and serves as the ureter of the metanephros only in caudal part. Muller duct differentiates into an oviduct (5), uterus (in marsupials and placental mammals (10)) and the vagina.

A – embryonic state ,1 – pronephros, 2 – mesonephros, 4 – sex gland, 7 – urinari bladder, 8 – cloaca, 9 - metanephros



Ontophylogenetic etiology of urogenital malformations: a pelvic position of kidneys, preservation of a mesonephros, doubling of the ureter, a bicornuate uterus, doubling the penis, violation of reduction of Wolffian channels in women, a duplex uterus and vagina (parallelism).

Draw in your drawing books:

1. Development of arterial arches in vertebrate animals

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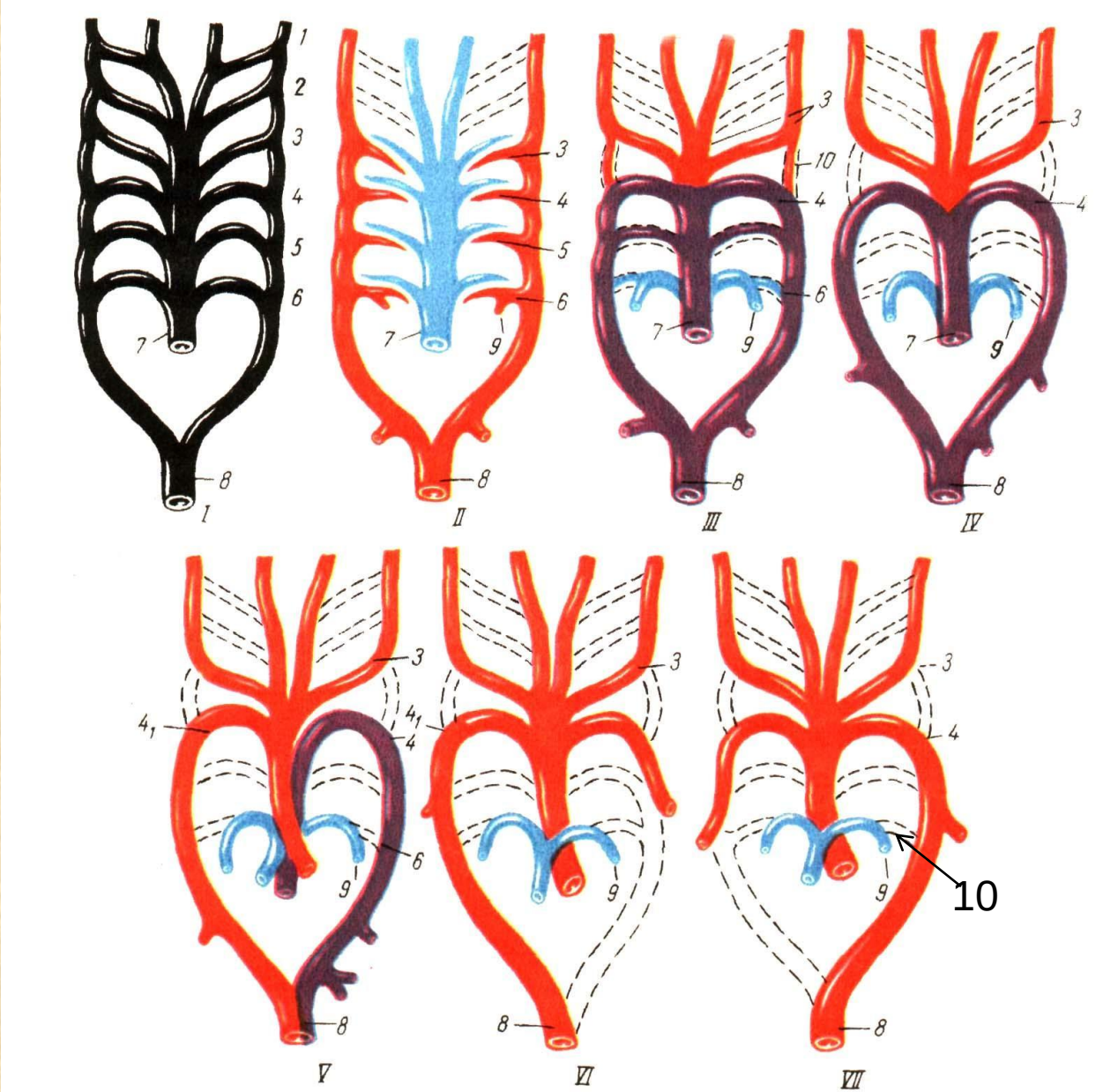
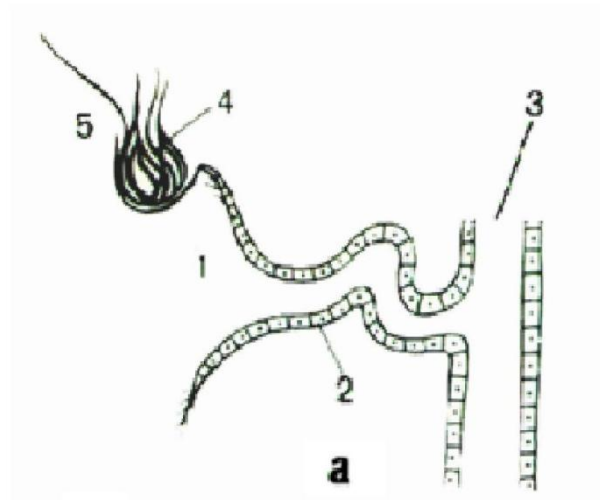
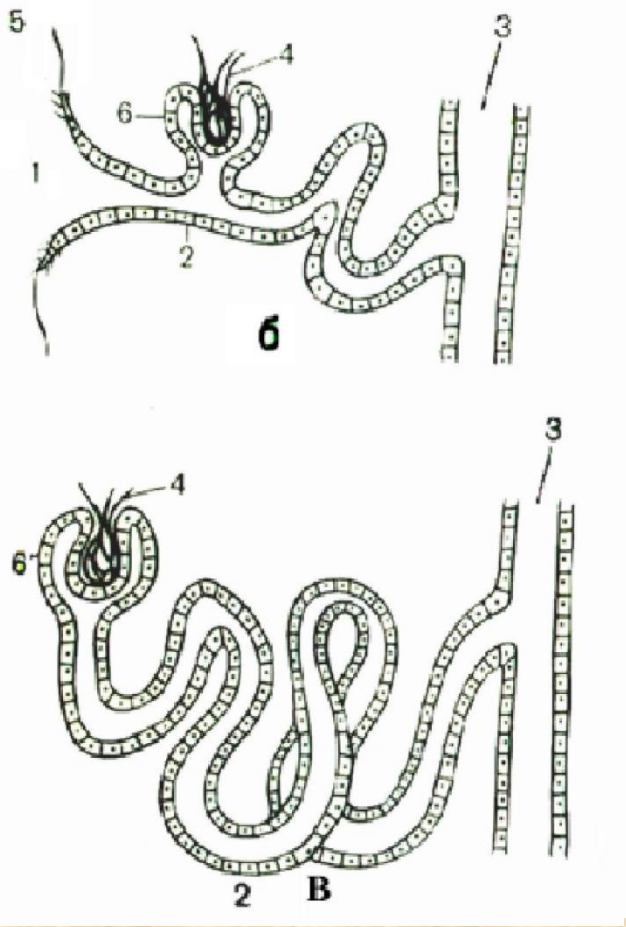


2. Evolution of the nephron

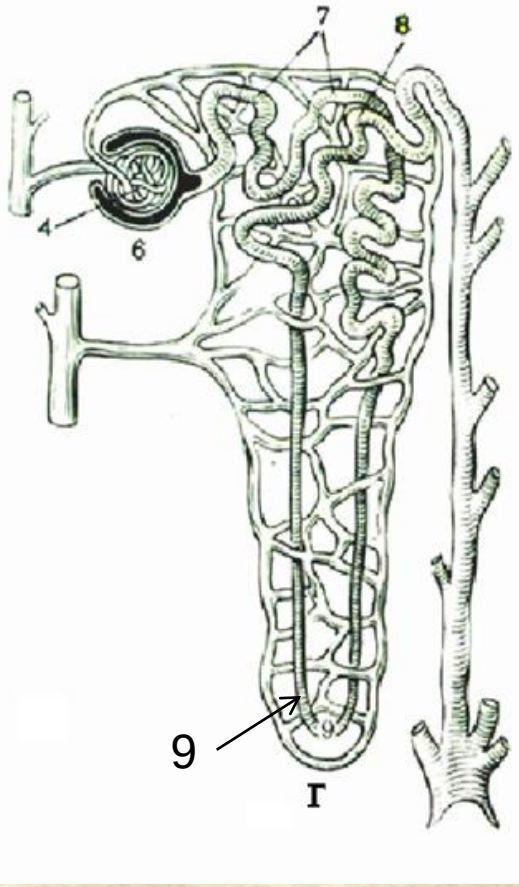
Pronephros



Mesonephros



Metanephros



1 – nephrostome, 2 – tubule of the nephron, 3 – ureter, 4 – glomerulus, 5 – coelom, 6 – capsule of the nephron, 7,8 – proximal and distal convoluted tubule, 9 - Henle loop