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HEART



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МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ
БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ
КАФЕДРА НОРМАЛЬНОЙ АНАТОМИИ

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СЕРДЦЕ

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Учебно-методическое пособие



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Содержит сведения о строении, развитии и рентгеноанатомии сердца человека.

Предназначено для студентов 1–2-го курсов медицинского факультета иностранных учащихся, обучающихся на английском языке. Может быть использовано при прохождении курса кардиологии, терапии, педиатрии, хирургических болезней, лучевой диагностики.

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HEART

Topic: Cardiovascular system. Heart. Structure of heart chambers. Structure of the wall of heart. Conducting system of heart. Systemic and pulmonary circulation.

The **heart** (cor) is a muscular organ that pumps blood throughout the body. Contraction of the heart is called *systole* and relaxations is *diastole*.

The heart's made up of **4 chambers**: 2 atria and 2 ventricles.

The outer groove that separates the atria and ventricles of the heart is coronary or atrioventricular sulcus (sulcus coronarius). The ventricles are divides by the anterior and posterior¹ interventricular sulci (grooves) (sulcus interventricularis anterior et sulcus interventricularis posterior).

The heart has (fig. 1, 2):

- 1) apex of heart (apex cordis) faces downward, forward, and to the left;
- 2) base of heart² (basis cordis) faces upward, backward, and to the right;
- 3) anterior or sternocostal surface (facies anterior);
- 4) inferior or diaphragmatic surface (facies inferior);
- 5) right and left pulmonary surfaces (facies pulmonalis dexter et sinister);
- 6) right, left and inferior borders (margo dexter, margo sinister et margo inferior).

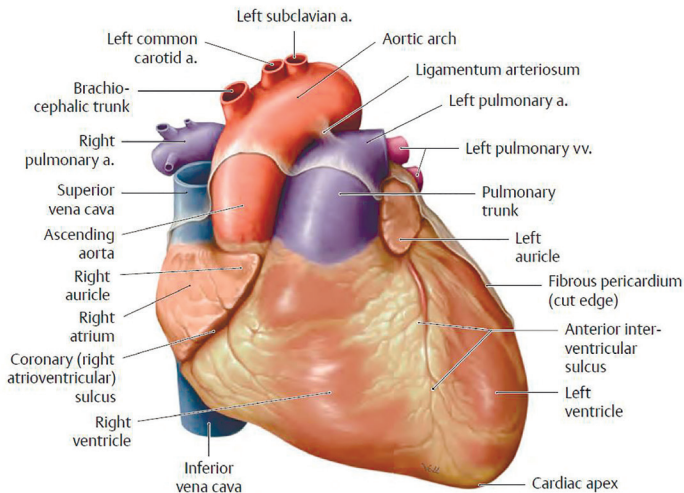


Fig. 1. Sternocostal surface of heart [3]

¹ Synonym: Inferior interventricular sulcus.

² Synonym: Posterior surface of heart.

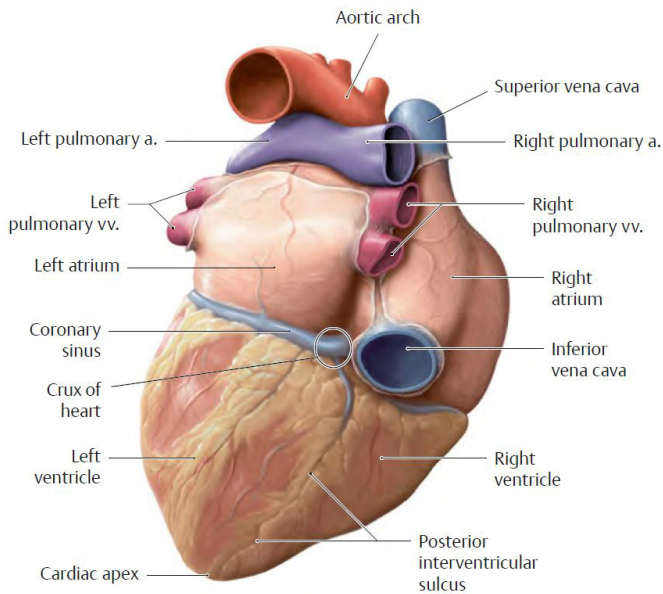


Fig. 2. Diaphragmatic surface of heart [3]

The right and left atria of the heart are separated by a thin tissue wall known as the *interatrial septum* (septum interatriale) which has oblique direction (according to that the left atrium locates posteriorly since the right one locates anteriorly).

The right and left ventricles also separated by the septum — *interventricular septum* (septum interventriculare), which is concave in shape (i. e. bulges into the right ventricle). It consists from 2 parts: lower or **muscular** part (pars muscularis) of the interventricular septum is also the major part, which is thick and muscular and the upper or **membranous** part (pars membranacea), which is thin, membranous and formed of fibrous tissue which covered on both sides with the endocardium.

STRUCTURE OF HEART CHAMBERS

RIGHT ATRIUM

The *right atrium* (atrium dextrum) is a cube shaped chamber of the heart. It is located in the upper right corner of the heart, superior to the right ventricle.

The atrium contains the orifices of the superior and inferior cava veins.

The inner surface of the right atrium is smooth except of a small frontal area and the inner surface of the appendage — *right auricle* (*auriculum dextrum*), where there are located the *pectinate muscles* (*musculi pectinati*) which form a series of small vertical columns (fig. 3).

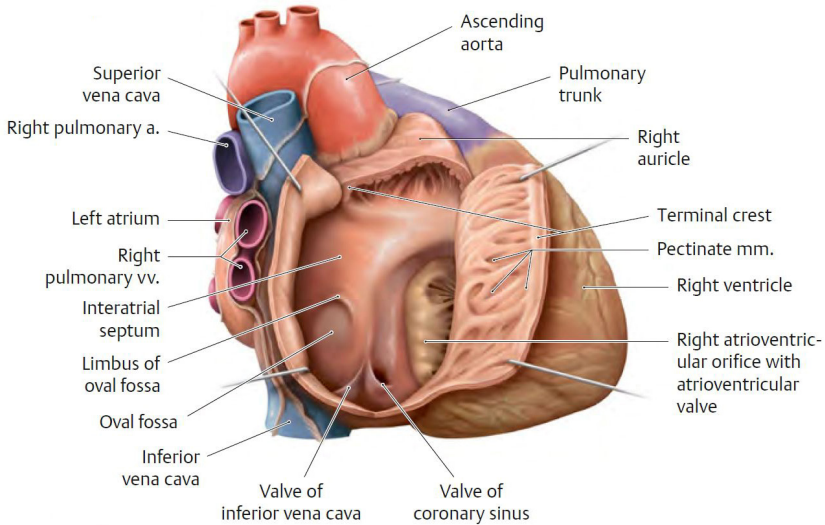


Fig. 3. Right atrium of heart [3]

Superiorly the pectinate muscles are continuous to the *terminal crest* (*crista terminalis*) which serves as the origin for the pectinate muscles. The terminal crest projected to the shallow depression on the external surface of the atrium known as the *terminal sulcus* (*sulcus terminalis*).

On the interatrial septum exists an *oval fossa* (*fossa ovalis*), which is bounded by a raised edge — *limbus of oval fossa* (*limbus fossa ovalis*). This depression is a remnant of the oval foramen through which the atria communicate during the intrauterine period of ontogenesis.

Internally, on the posterior wall of the atrium, between the orifices of the superior and inferior cava vein is a small ridge — *interveinous tubercle* (*tuberculum intervenosus*). This ridge is thought to direct the flow of blood in the embryo from the superior vena cava to the right atrioventricular orifice.

A variably sized *valve of inferior vena cava*¹ (*valvula venae caevae inferioris*) stretches from the inferior margin of the orifice of the inferior cava vein to the limbus

¹ Synonym: Semilunar valve.

of the oval fossa. This fold has vital importance for the embryo because it directs blood from the inferior cava vein through the oval foramen into the left atrium.

Below this valve, between the openings of the inferior cava vein and the right atrioventricular orifice is located the coronary sinus of the heart (*sinus coronarius cordis*). It collects blood from the veins of the heart and drains it to the right atrium.

LEFT ATRIUM

The *left atrium* (*atrium sinistrum*) is grossly cuboidal. It is the most superior and posterior portion of the heart and is obscured anteriorly by the pulmonary trunk and ascending aorta.

It is smaller by volume than the right atrium but has thicker walls.

The left atrial appendage, also known as *left auricle* (*auricula sinistra*), is long and narrow which curves anteriorly from the leftward around the pulmonary trunk, overlying part of the left coronary artery. Its inner surface is lined by the small *pectinate muscles* (*musculi pectinati*), unlike the main cavity which has smooth walls.

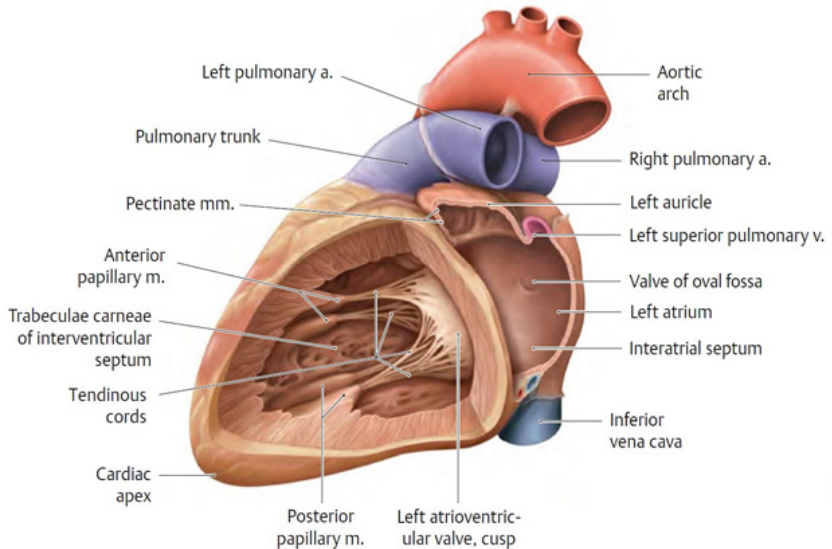


Fig. 4. Left atrium of heart [3]

The left atrium is filled with blood via **4 pulmonary veins**: the left (superior and inferior) and the right (superior and inferior), and emptied through the left *atrioventricular orifice* (*ostium atrioventriculare sinistrum*) into the left ventricle.

RIGHT VENTRICLE

The *right ventricle* (ventriculus dexter) is the most anteriorly situated cardiac chamber since it is located immediately behind the sternum.

The right ventricle is triangular in shape when viewed from the front and it curves over the left ventricle. When seen from the apex, the right edge of the right ventricle is sharp, forming the acute margin of the heart. In a cross-sectional view, the ventricle cavity appears like a crescent.

From the left upper angle of the right ventricle, also known as *arterial* or *pulmonary conus*¹ (conus arteriosus), arises the pulmonary trunk.

The *right atrioventricular valve* or *tricuspid valve* (valva atrioventricularis dextra s. valva tricuspidalis) exists in the right atrioventricular orifice of the heart between the right atrium and the right ventricle. It prevents backflow of blood from the right ventricle into the right atrium during right ventricular systole (fig. 5).

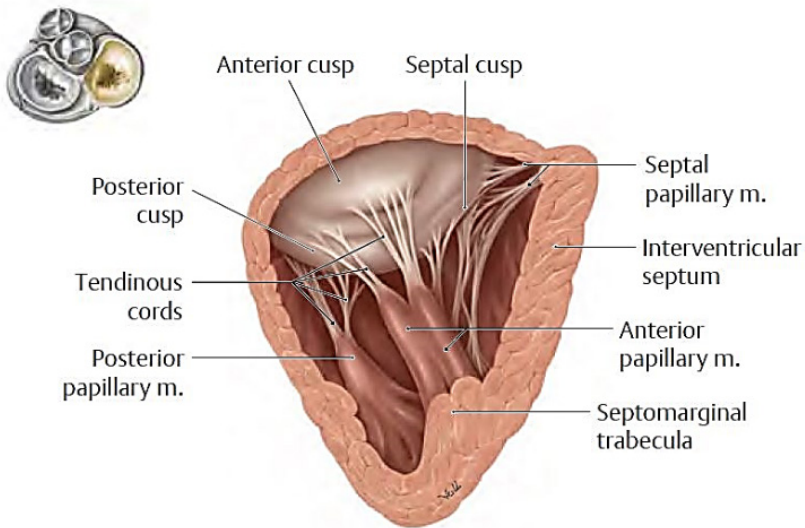


Fig. 5. Tricuspid valve [3]

Tricuspid valve has **3 leaflets** (cusps):

- anterior leaflet (cusp) (cuspis anterior);
- inferior leaflet² (cusp) (cuspis posterior);
- septal leaflet (cusp) (cuspis septalis).

¹ Synonym: Infundibulum of right ventricle.

² Synonym: Posterior cusp.

The free margins of the cusps face into the ventricle.

Tendinous cords (chordae tendineae) are attached to them.

Other ends of these threads are attached to the apices of the *papillary muscles* (musculi papillares).

The papillary muscles are conical muscular extensions, with the apex projecting into the cavity of the ventricle and the base continues into the ventricular wall.

There are **3 papillary muscles** in the right ventricle:

- anterior papillary muscle;
- inferior¹ papillary muscle;
- septal papillary muscle.

From the right ventricle, the blood enters to the pulmonary trunk through an *opening of pulmonary trunk* (ostium trunci pulmonalis) mediated by a *pulmonary valve* (valva trunci pulmonalis) which prevents the backflow of blood from the pulmonary trunk to the right ventricle during diastole of right ventricle (fig. 6).

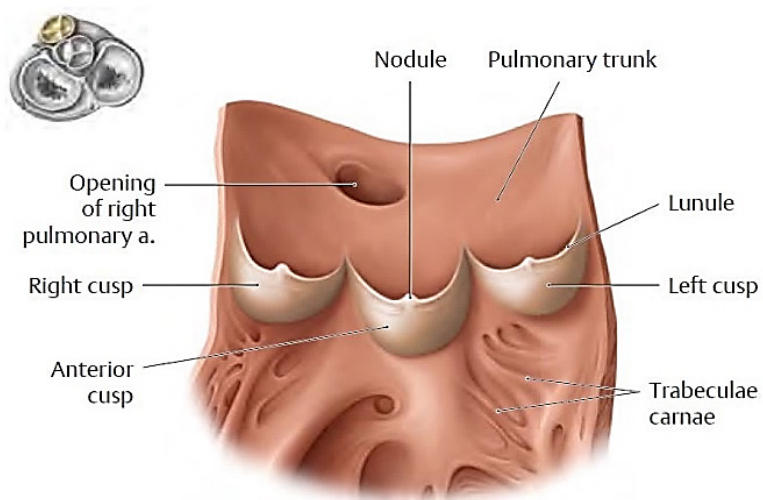


Fig. 6. Pulmonary trunk valve [3]

The valve of pulmonary trunk is composed of **3 semilunar leaflets** (cusps) called the semilunar valvulae:

- anterior semilunar leaflet (cusp) (valvulae semilunaris anterior);
- left semilunar leaflet (cusp) (valvula semilunaris sinistra);
- right semilunar leaflet (cusp) (valvula semilunaris dextra).

¹ Synonym: Posterior papillary muscle.

In the middle of the free border of each leaflet is located a small *nodule of semilunar leaflet* (nodulus valvulae semilunaris). The nodules close the valves tightly. On each side of this nodule, there are thin marginal segments of the valvulae called the *semilunar lunules* (lunulae valvulae semilunaris).

LEFT VENTRICLE

The *left ventricle* (ventriculus sinister) has a conical shape, with a wall two (or three) times thicker than the wall of right ventricle

Between the left ventricle and left atrium, exists the *left atrioventricular orifice* (ostium atrioventriculare sinistrum) which contains a *left atrioventricular* or *mitral valve*¹ (valva mitralis) (fig. 7).

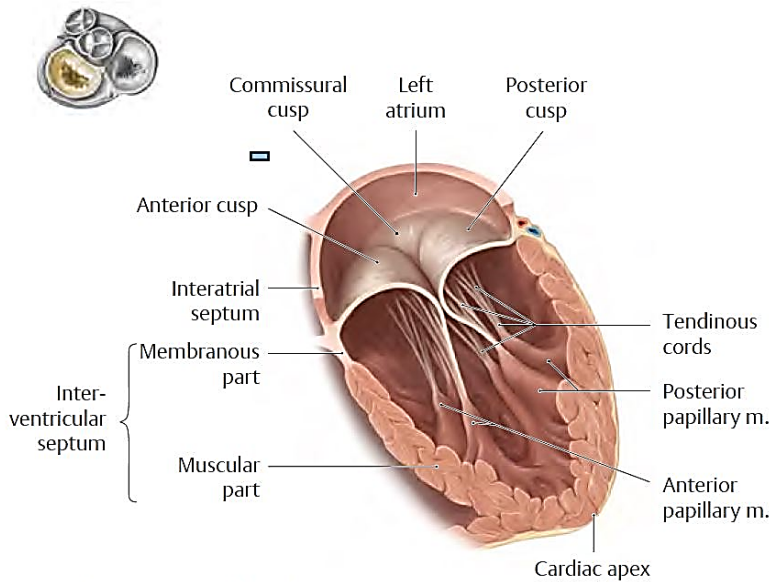


Fig. 7. Bicuspid (mitral) valve [3]

The valva has **3 leaflets** (cusps):

- anterior leaflet (cusp) (cuspis anterior);
- posterior leaflet (cusp) (cuspis posterior);
- commissural leaflet (cusp) (cuspides commisurales).

¹ Synonym: Bicuspid valve.

The tendinous cords are attached to the free margins of the cusps.

There are **2 papillary muscles** (anterior and posterior) in the left ventricle. Each muscle sends tendinous cords to both leaflets of the mitral valve.

The *aortic valve* (valva aortae) is located in the *aortic orifice* (ostium aortae). The aortic valve is similar in structure to the valve of pulmonary trunk.

It has **3 leaflets** (cusps) (fig. 8):

- non-coronary leaflet¹ (cusp) (valvula noncoronaria);
- left coronary leaflet (cusp) (valvula coronaria sinister);
- right coronary leaflet (cusp) (valvula coronaria dextra).

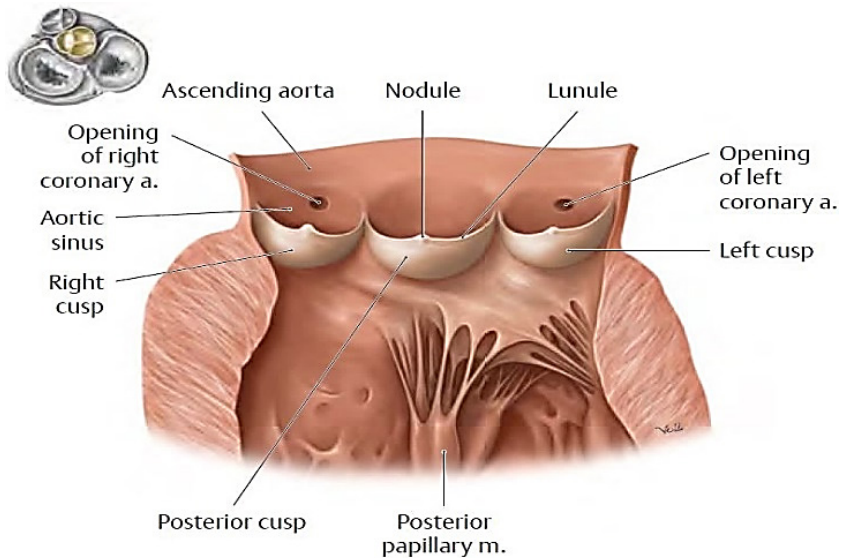


Fig. 8. Aortic valve [3]

The nodules on their free margins are more conspicuous than those on the valves of pulmonary trunk. Semilunar lunules of aorta are also present.

Between the wall of aorta and aortic leaflets is located **3 aortic sinuses**:

- right aortic sinus (sinus coronaries dexter aortae);
- left aortic sinus (sinus coronaries sinister aortae);
- noncoronary aortic sinus (sinus noncoronarius aortae).

¹ Synonym: Posterior semilunar leaflet of aortic valve.

STRUCTURE OF THE WALL OF HEART

The wall of the heart is made up of **3 layers** (fig. 9):

- endocardium (inner layer);
- myocardium (middle layer);
- epicardium (outer layer, form by visceral pericardium).

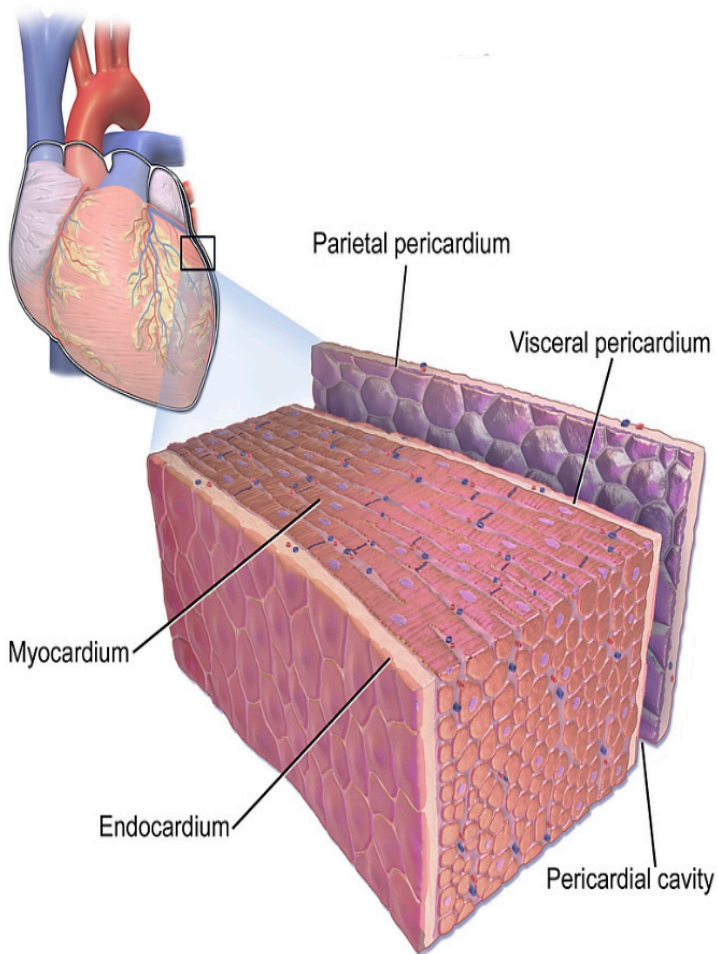


Fig. 9. Wall of the heart [8]

Structure of myocardium:

The atria are formed by **2 muscular layers** (fig. 10):

- longitudinal (inner layer);
- circular (outer layer).

The longitudinal layer is individual for each atrium and the circular layer is common for the atria.

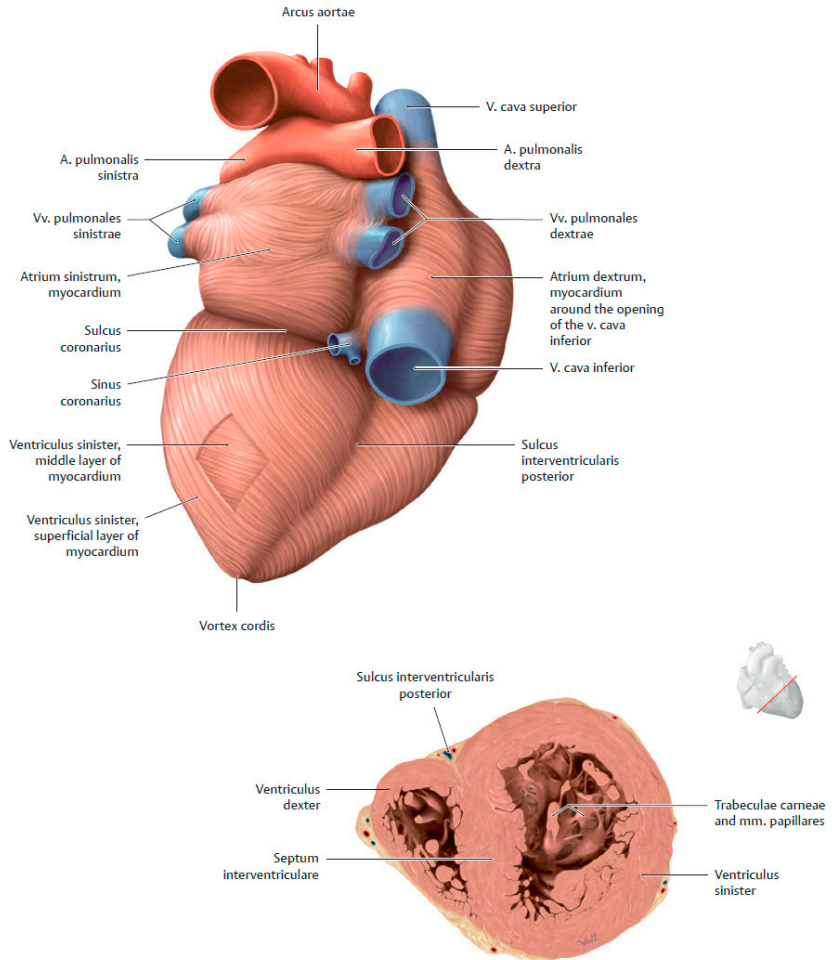


Fig. 10. Myocardium of heart [3]

The ventricles are formed by **3** muscular *layers* (fig. 10):

- longitudinal layer (outer layer);
- circular layer (middle layer):
- longitudinal layer (inner layer).

The longitudinal layer is common for each ventricle and the circular layer is individual for the ventricles. The musculature of the atria and ventricles arise from *2 fibrous rings* (annuli fibrosi), which surround the right and left atrioventricular orifices (fig. 11). The fibrous ring keeps the caliber of the orifice constant.

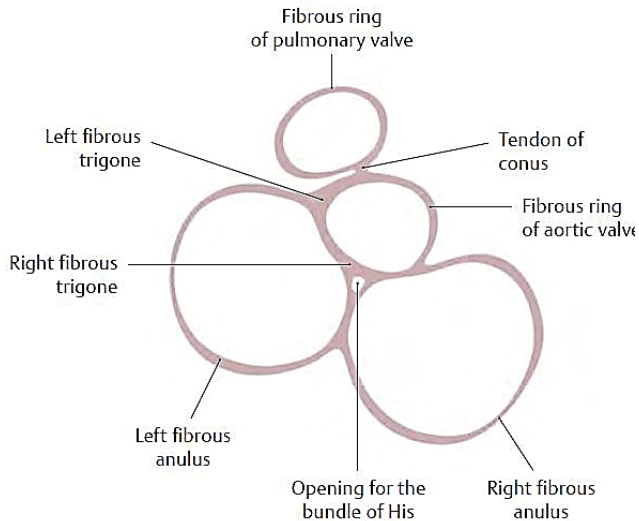


Fig. 11. Fibrous rings of the heart [3]

The outer longitudinal layer arises from the fibrous ring of ventricle, then descends to the heart apex and forms a *whirled mass* (vortex cordis) which continues to the inner longitudinal layer of another ventricle and attaches to another fibrous ring.

CONDUCTING SYSTEM OF HEART

The *cardiac conduction system* is a collection of nodes and specialized conduction cells that initiate and coordinate contraction of the heart muscle (fig. 12).

The *conducting system includes*:

- 1) sinuatrial node (nodus sinuatrialis);

- 2) atrioventricular node (nodus atrioventricularis);
- 3) antioventricular bundle¹ (fasciculus atrioventricularis);
- 4) right and left bundle branches (crus dextrum and crus sinistrum);
- 5) subendocardial brunches² (subendocardial plexus of conduction cells).

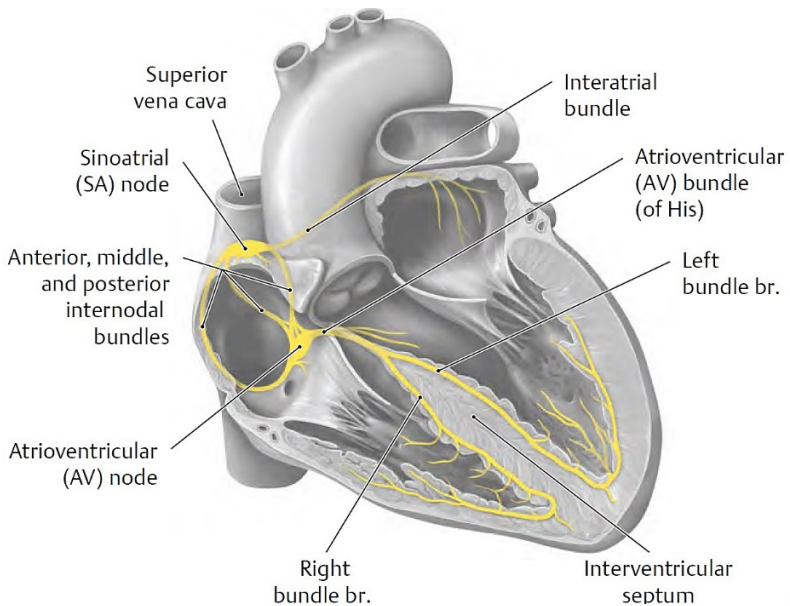


Fig. 12. Conductive system of heart [3]

The *sinuatrial node* is located between the superior vena cava and the right auricle (right atrium).

Stimulation is usually conducted from the sinuatrial node to the atrioventricular node. The *atrioventricular node* is located in the right atrium's wall, near the septal leaflet of the tricuspid valve.

Stimulation from the atrioventricular node transmits along the bundle of His into both ventricles.

The *bundle of His* is located in the septum between the ventricles. It's divided into the right and left bundle branches and terminated by subendocardial brunches.

¹ Synonym: His bundle.

² Synonym: Purkinje fibers.

SYSTEMIC AND PULMONARY CIRCULATION

The *systemic circulation* is the passage of arterial blood from the left ventricle of heart via *aorta* to the organs and tissues, that receive of its oxygen in exchange for carbon dioxide, and return of deoxygenated blood via the *superior* and *inferior vena cavae* to the right atrium of heart.

The deoxygenated blood shoots down from the right atrium to the right ventricle. Then the heart pumps it out of the right ventricle into the pulmonary trunk to begin pulmonary circulation. This blood moves to the lungs, exchanges carbon dioxide for oxygen, and returns to the left atrium via **4 pulmonary veins**: (right (superior and inferior) and left (superior and inferior)). Then oxygenated blood shoots down to the left ventricle where starts the systemic circuit (fig. 13).

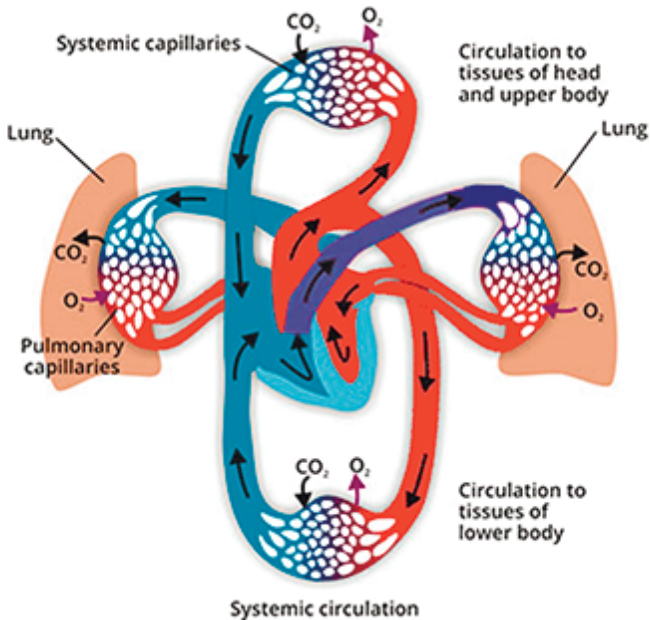


Fig. 13. Systemic and pulmonary circulation [5]

ARTERIES OF HEART

Topic: Topography of heart. Projection of heart valves on the anterior wall of chest, and their auscultation points. Pericardium. Roentgen anatomy of heart. Arteries and veins of heart. Development of heart.

The heart supplied by:

- right coronary artery (a. coronaria dextra);
- left coronary artery (a. coronaria sinistra).

The *coronary arteries* emerge from the aortic bulb below the superior margin of the aortic semilunar valve (fig. 14). They course to the coronary groove and formed an *arterial ring* which is located in a horizontal plane. That ring is a functional adaptation for the collateral circulation of the heart.

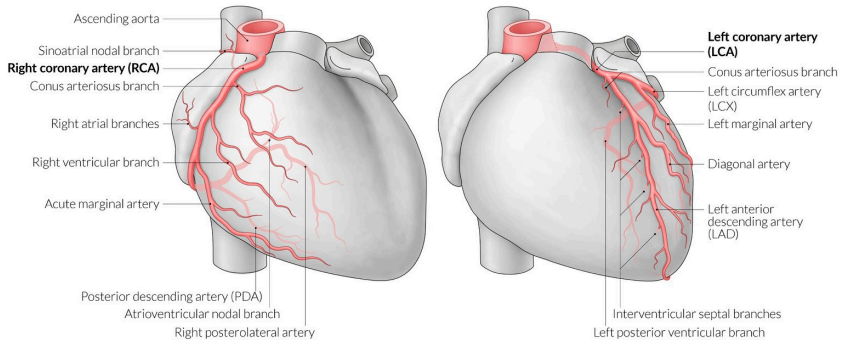


Fig. 14. Coronary arteries of the heart [4]

RIGHT CORONARY ARTERY

The right coronary artery emerges from the right semilunar valvula of aorta and passes laterally between the aorta and auricle of the right atrium. Then it rounds the right border of the heart within the coronary groove and courses over diaphragmatic surface, where its continuous to the posterior interventricular artery ¹(branch) (ramus interventricularis posterior). These branches descend along the posterior interventricular groove to the apex of heart where it anastomoses with the anterior interventricular branch of left coronary artery.

The branches of the right coronary artery are vascularizing:

- right atrium;
- interatrial septum;
- most of anterior and all posterior walls of the right ventricle;
- small part of the posterior wall of left ventricle;
- posterior $\frac{1}{3}$ of the interventricular septum;

¹ Synonym: Posterior descending artery (PDA).

- papillary muscles of the right ventricle;
- posterior papillary muscle of the left ventricle;
- SA and AV nodes.

LEFT CORONARY ARTERY

The *left coronary artery* emerges from the left semilunar valvula of aortic bulb and courses in the coronary groove between the left atrium and the pulmonary trunk.

The left coronary artery gives off 2 branches:

- anterior interventricular artery¹ (branch) (ramus interventricularis anterior);
- circumflex artery (branch) (ramus circumflexus).

The *anterior interventricular artery* descends along the anterior interventricular groove to the apex of heart and giving branches to the anterior walls of right and left ventricles and the interventricular septum.

The *circumflex artery* runs in the coronary groove leftward between the left auricle and ventricle to the left margin of the heart, then it turns to the diaphragmatic surface and reaches the right coronary artery. It branching out to the left atrial branches, left marginal branch and branches to the posterior wall of left ventricle.

The branches of the left coronary artery are vascularizing:

- left atrium;
- all anterior and most of the posterior wall of left ventricle;
- small part of the anterior wall of the right ventricle;
- anterior ²/₃ of the interventricular septum;
- anterior papillary muscle of the left ventricle.

VEINS OF HEART

Venous blood from the heart drains along three routes into:

- 1) coronary sinus (sinus coronaries cordis);
- 2) anterior veins of heart (empties the blood directly into the right atrium)
- 3) small veins of heart (empties the blood into the right atrium and right ventricle).

VEINS OF CORONARY SINUS

The coronary sinus is located on the posterior surface of heart in the coronary sulcus between the left atrium and the left ventricle. It's opens into the right atrium near with the interventricular septum and orifice of inferior cava vein (fig. 15).

¹ Synonym: Left anterior descending artery (LAD).

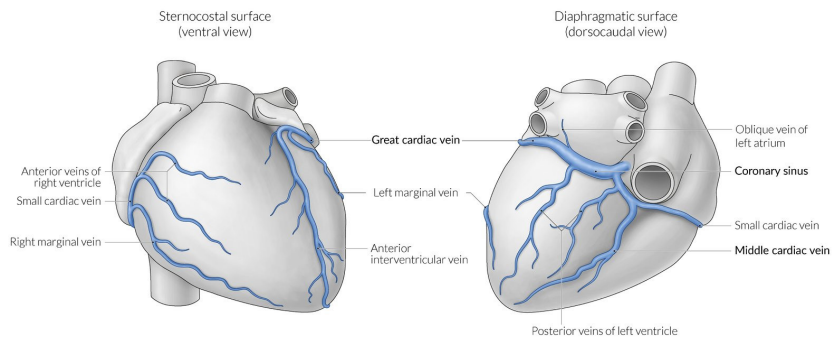


Fig. 15. Veins of heart [4]

The following **tributaries drains into the coronary sinus**:

1) *great cardiac vein* (v. cordis magna) arises at the heart apex, ascends in the anterior interventricular sulcus of the heart then turns leftward and curving over the left side of heart where it continuous into the coronary sinus;

2) *middle cardiac vein* (v. cordis media) runs in the posterior interventricular sulcus and drains into the coronary sinus;

3) *small cardiac vein*¹ (v. cordis parva) is located on the anterior surface of the heart, in a groove between the right atrium and right ventricle. It travels within this groove onto the posterior surface of the heart, where it empties into the coronary sinus or middle cardiac vein;

4) *posterior vein of the left ventricle* (v. posterior ventriculi sinistri) is one or more small venous trunks on the posterior surface of left ventricle, which empties into the coronary sinus;

5) *oblique vein of the left atrium* (v. obliqua atrii sinistri) is a small vein of the posterior surface of the left atrium.

All tributaries, except the oblique vein of the left atrium, contain valves at their junction with the coronary sinus.

PERICARDIUM

The *pericardium* (pericardium) is the fibrous sac that surrounds the heart. It's contains the heart and the juxtacardiac parts of its great vessels.

It can be divided into (fig. 16, 17, 18):

- 1) fibrous pericardium (pericardium fibrosum);
- 2) serous pericardium (pericardium serosum).

¹ Synonym: Right coronary vein.

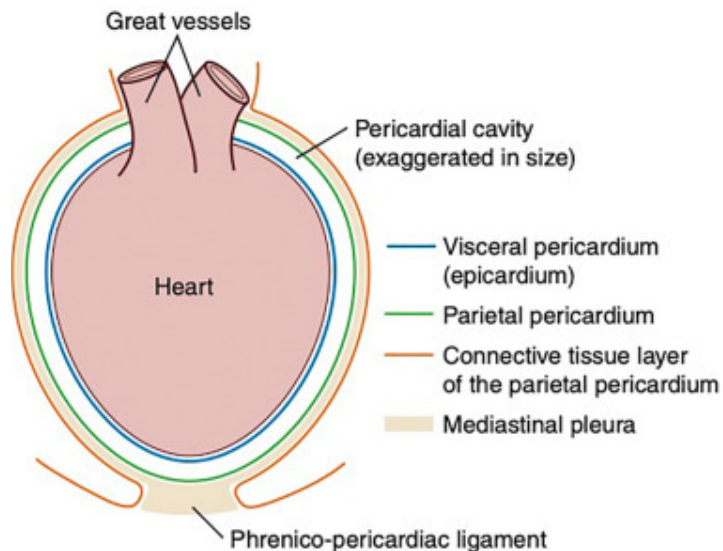


Fig. 16. Pericardium (diagram) [6]

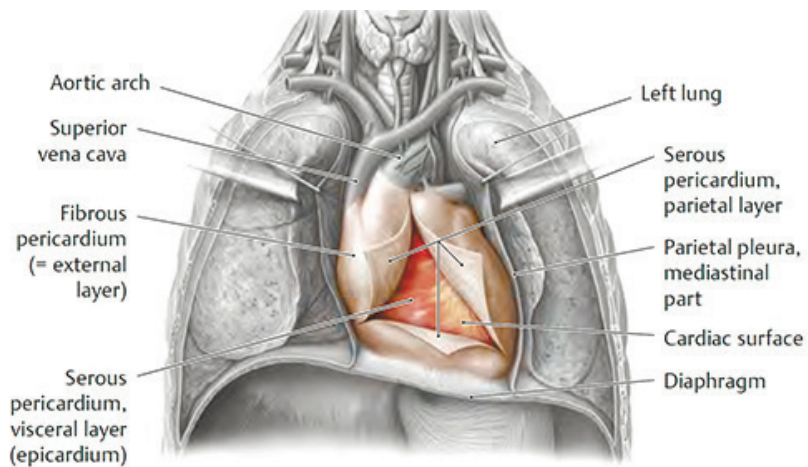


Fig. 17. Pericardium [3]

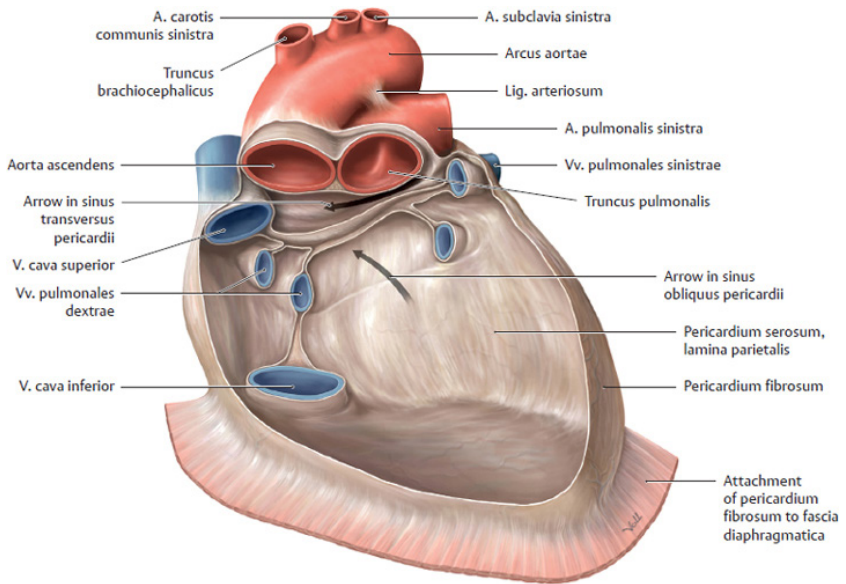


Fig. 18. Sinuses of pericardium [3]

The *fibrous pericardium* merges with the adventitia of the great vessels of heart and attaches anteriorly to the inner surface of the sternum by sternopericardial ligaments, to the central tendon of the diaphragm and to the mediastinal pleura on both sides.

The serous pericardium consists from **2 layers**:

- 1) visceral layer or epicardium;
- 2) parietal layer, which is fuses with the inner surface of fibrous pericardium and lines it.

Between the visceral and parietal layer of serous pericardium located the *pericardial cavity* (cavum pericardii) containing a small amount of *serous fluid* (liquor perikardii).

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 passage behind the aorta and pulmonary trunk is called the *transverse sinus of pericardium* (sinus transverses pericardii). The space between the inferior vena cava and the left pulmonary veins is *the oblique sinus of pericardium* (sinus obliquus pericardii) (fig. 18).

ROENTGEN ANATOMY OF HEART

The main position for the study of the heart is the anterior position of the human (the path of the X-rays is sagittal, dorsoventral). In this position, two light lung fields are visible, between which there is an intense dark median shadow.

Median shadow formed by the shadows of:

- thoracic spine;
- sternum;
- heart;
- large vessels of heart;
- organs of the posterior mediastinum.

However, this median shadow is considered only as a silhouette of the heart and large vessels, because the other formations mentioned (spine, sternum, etc.) usually do not appear within the cardiovascular shadow.

The lateral contours of this shadow look like protrusions separated from each other by depressions. These protrusions are called arcs. They correspond to those parts of the heart and the large vessels associated with it, which form the edges of the cardiovascular silhouette.

Lateral contours of the cardiovascular shadow have **2 arcs on the right** and **4 on the left** (fig. 19).

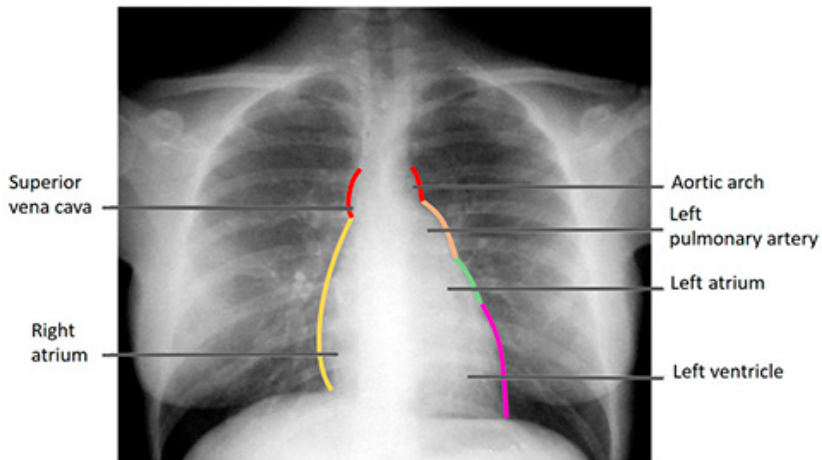


Fig. 19. X-ray contours of heart [3]

The *right contour* formed by:

- upper arc is formed by the ascending aorta and the superior vena cava (this arc is called the vascular);

- lower arch is well expressed, which corresponds to the right atrium.

The *left contour* formed by:

- uppermost (first) arch corresponds to the arch and the beginning of the descending part of the aorta;
- second — to the pulmonary trunk;
- third — to the auricle of left atrium;
- fourth — to the left ventricle.

The left atrium, located for the most part on the posterior surface, is not edge-forming in the dorsoventral course of the rays and therefore is not visible in the anterior position. For the same reason, the right ventricle located on the anterior surface is not contoured, which also merges with the shadow of the liver and diaphragm below.

The place of transition of the arc of the left ventricle to the lower contour of the cardiac silhouette is marked radiologically as the *apex of heart*.

TOPOGRAPHY OF HEART

The heart is located asymmetrically in the *anterior mediastinum*. Its greater part is located on the left from the midline, and only the right atrium and both venae cava on the right (fig. 20).

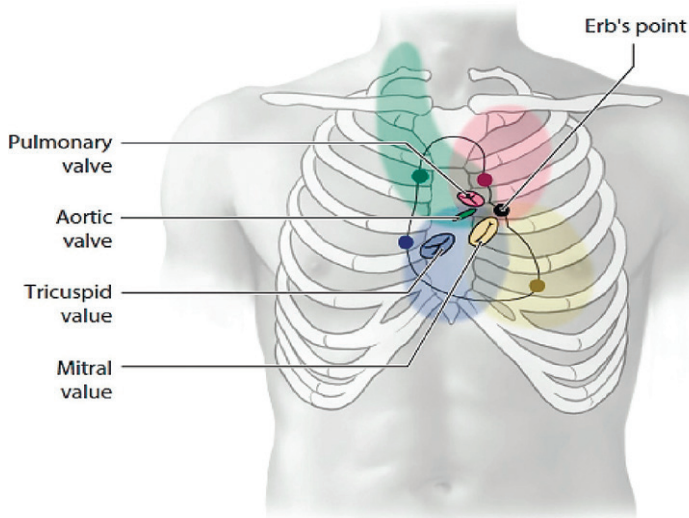


Fig. 20. Topography of heart [7]

The long axis of the heart extends obliquely downward from right to left and from back to front. Position and shape of the heart depends on constitution, gender and age. Distinguished **3 types of heart position**: oblique, horizontal, vertical.

The *apex* of the heart is located in the 5th intercostal space: 1–1,5 cm medial to the left midclavicular line.

The surface projections of heart represent points on the thoracic wall that map out the outline and valves of the heart. These include four borders (superior, right, inferior, left) and four valves (left atrioventricular, right atrioventricular, aortic, pulmonary).

Projection of heart on the thoracic wall:

- *superior* border projected on the level of upper borders of 3rd costal cartilages (from both sides of sternum);
- *right* border projected on 1–1,5 cm from the right border of sternum and courses from the 3rd costal cartilage to the 5–6th costal cartilage;
- *left* one projected from the 3rd costal cartilage (or 2nd intercostal space) to the apex of heart;
- *inferior* border projected from the sternal end of the right 5–6th costal cartilage to the apex of heart.

Auscultation sites for listening of heart (valve) sounds:

- *aortic valve*: over the right 2nd intercostal space, near with sternum;
- *pulmonary valve*: over the left 2nd intercostal space, near with sternum;
- *tricuspid valve*: the 4 and 5th intercostal space near with right sternal border (additional points located on the base of xiphoid process and from the left side of sternum in the 5th intercostal space)
- *mitral valve*: over the apex of heart in the left 5th intercostal space.

In cardiology, ***Erb's point*** refers to the 3rd intercostal space on the left sternal border where the heart sound is best auscultated.

Projection of heart valves:

- orifice of aortic valve — is on the level of the left 3rd costal cartilage;
- orifice of pulmonary trunk — is behind the sternum and slightly to the right.
- both atrioventricular orifices are projected on a straight line which is passing on the sternum from the left 3rd intercostal space to the right 5th intercostal space.

DEVELOPMENT OF HEART

The heart forms from the *mesoderm* (embryonic connective tissue) around 18 to 19 days after fertilization. It's begins to develop near the head of the embryo in a region known as the *cardiogenic area* (fig. 21). Following chemical signals

called factors from the underlying endoderm (another primary germ layer), the cardiogenic area begins to form two strands called the *cardiogenic cords*.

As the cardiogenic cords develop, a lumen rapidly develops within them. At this point, they are referred to as *endocardial tubes*.

The two tubes migrate together and fuse to form a *single primitive heart tube*.

The primitive heart tube quickly forms **5 distinct regions**:

- truncus arteriosus;
- bulbus cordis;
- primitive ventricle;
- primitive atrium;
- sinus venosus.

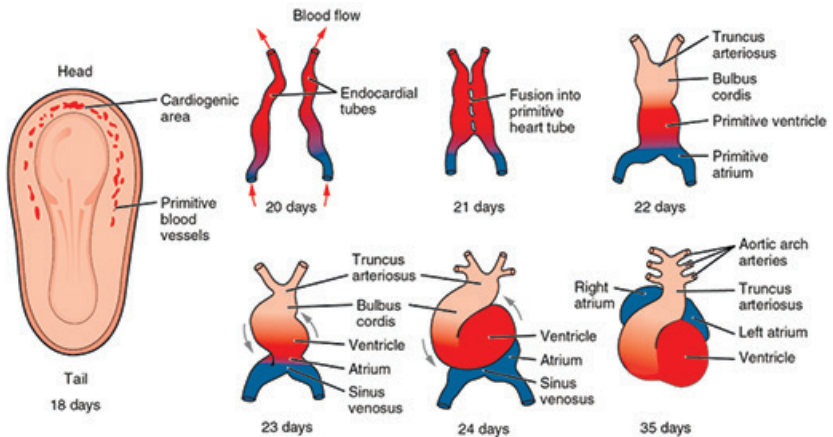


Fig. 21. Development of heart [6]

Truncus arteriosus will eventually divide and give rise to the ascending aorta and pulmonary trunk.

Bulbus cordis develops into the *right ventricle*.

Primitive ventricle forms the *left ventricle*.

Primitive atrium becomes the **anterior portions** of both the *right* and *left atria*, and the *two auricles*.

Sinus venosus develops into the **posterior portion** of the *right atrium*, the *SA node*, and the *coronary sinus*.

As the primitive heart tube elongates, it begins to fold within the pericardium, eventually forming an S shape, which places the chambers and major vessels into an alignment similar to the adult heart.

Partitioning of the atria and ventricles by the interatrial septum, interventricular septum and atrioventricular is complete by the end of the 5th weeks (fig. 22).

Partitioning of the heart into four chambers

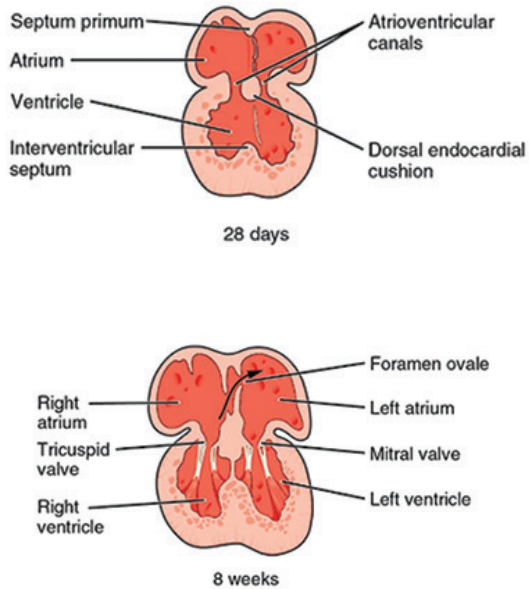


Fig. 22. Partitioning of heart into four chambers [6]

The **atrioventricular valves** forms between weeks 5th and 8th, and the **semilunar valves** forms between weeks 5th and 9th.

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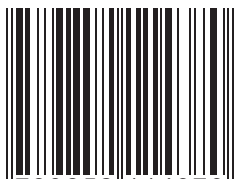
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