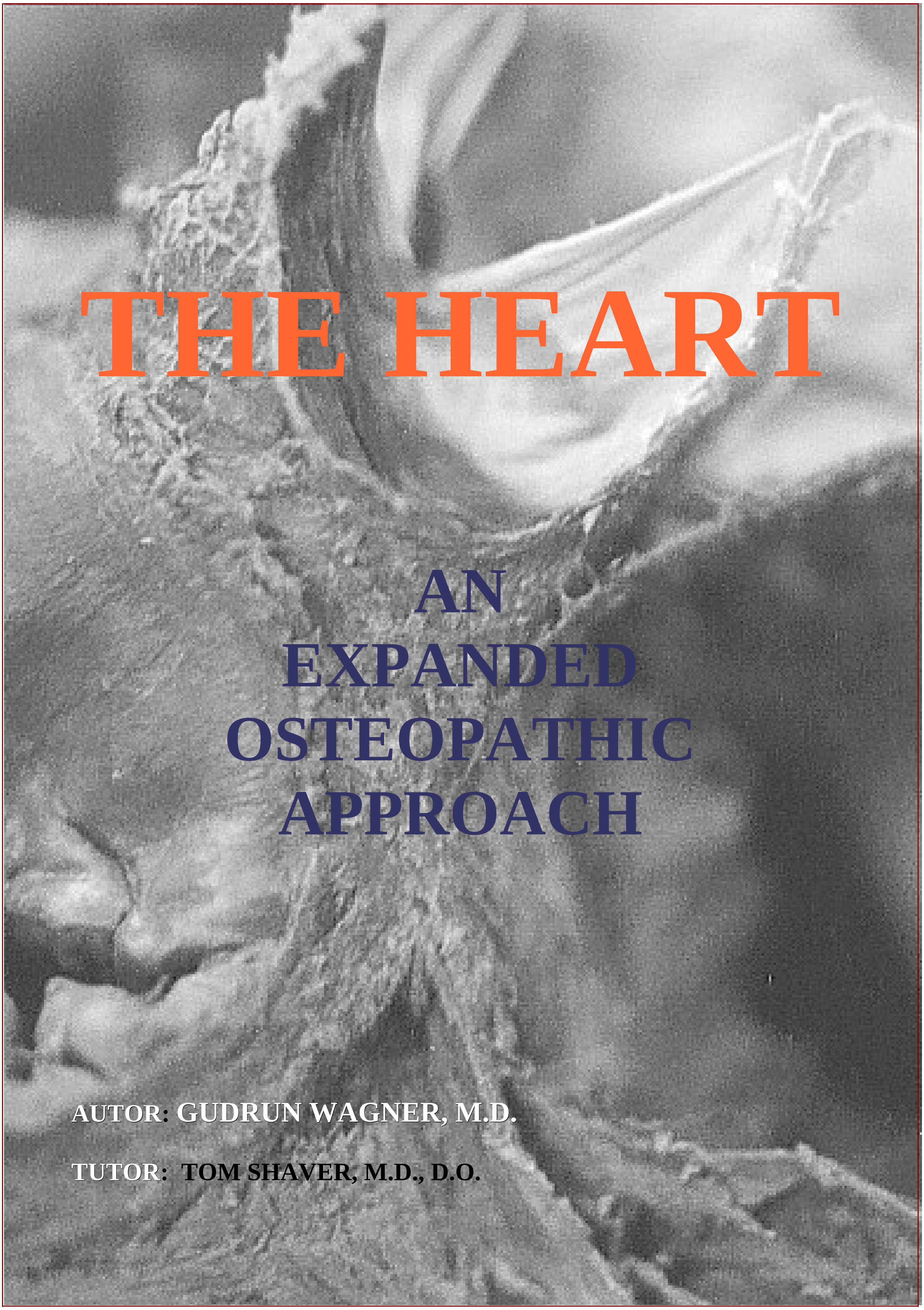

THE HEART

AN EXPANDED OSTEOPATHIC APPROACH

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1. Preface

It was and still is my concern and a gift to me to touch the heart - to grasp it, to understand, to find and be allowed to search, to believe in its recognition and to meet the heart in its depths.
I hope to touch, move and bring you closer to the topic with the following study.

I want to thank all those who showed me ways to the heart, into the heart and within, or who have kept me company for part of the way.

I want to give special thanks to my tutor, Tom Shaver M.D., D.O., whose support allowed me to work in America; the anatomist James Nemitz, Ph.D., and Bill Martin, Ph.D.; the West Virginia School of Osteopathic Medicine, Lewisburg, WV, USA, who were with me during my search; professor Adriana Gittenberg-de Groot, Leiden University, for her embryological literature; and the osteopaths Bernard Ligner, D.O., Jean Arlot, D.O., Stuart Korth, D.O., James Jealous, D.O., Patrick v. d. Heeden, D.O., whose lessons gave me an idea of osteopathy's potential.

I also want to thank Florian Jäger for the translation.

2. Introduction

The heart is there: We can see it and touch it, but the truth lies much deeper, hidden in the layers of this organ, in the depths of its existence, in its origin.

We meet this origin with each filling of blood of each little angle; because the nourishing, filling blood must stream. Constantly. Thus, this one organ that consists of muscle, nerves and connective tissue, ensures our lives. And we know that connective tissue has a memory, we know it has the potential of becoming, of altering its current state.

We will travel through time, on a journey through dreamscapes, …a trip with our hearts to pieces of the heart. We travel with and into the history of the pulsing stream.

Knowing about the anatomical and physiological basics, we will follow the truths of embryology to unveil the secrets of the heart.

Just like a carefully guarded treasure, it is the center around which everything revolves.

The fibrous skeleton of the heart. The task, the position, the centeredness, evolution, multiple relations and basic tissue of this very fibrous skeleton will tell us about its significance.

A broader osteopathic concept does not only prescribe the knowledge about the exterior form, function and interconnections of the heart, but the understanding of its innermost being. It is certain that this endeavour of regarding solely the heart, though very important to me, can only be one of many parts of an osteopathic concept. It is just as important that unifying moves and movement axes draw our attention, so we can detect functional similarities in their vast entity and adapt our osteopathic therapeutic efforts accordingly.

Let us set out on our journey with small steps and progress slowly, always aware of our environment. Our destination remains vague, shifting from moment to moment; and it is probable that after the last word, our destination has become the point of departure for other journeys.

Vienna, 1999-2000

3. Basic principles

This study bases on the understanding of the heart as the basic principle to ensure the living functions of the entire organism.

The combination of the embryological, anatomical, physiological and, last not least, the osteopathic point of view clearly shows the central position of the heart which, constantly moving and manifesting asymmetry in the body's cavities, supports life.

In the beginning of my search for explanations and for relevant structures, I started to dissect a great number of hearts. First, I used preparations mounted in formaldehyde solution and discovered, after removing the pericardium, the inner structure as an essential functional principle. After carefully removing the atria, the atrioventricular valves were out in the open, and I tried to find a way to make the fibrous skeleton of the heart visible, the structure which supports the valves in the right spatial position. After removing the endocardium, too, I succeeded in various preparations to show the entire fibrous skeleton of the heart.

The next step consisted in showing the fibrous skeleton of the heart in relation to the entire body, i.e., in its position in the chest and in relation to the other inner organs. I realized this by using formaldehyde-mounted whole body preparations in which, after opening the thorax and, once more, preparing the fibrous skeleton of the heart, I was able to show the relations of the latter to the diaphragm and the lungs.
I used primarily the position of the fibrous skeleton's axes and showed their relations to other axes, with the main focus on the axes of the lungs.
In that way, a picture formed of the heart and the lungs as one functional unit.

The further proceedings were clear: arriving from an understanding of the embryological interactions and using basic osteopathic principles (the principle of the artery, movement is life) as point of departure, focusing any new ideas on the fibrous skeleton of the heart, and as a consequence, of course, developing new osteopathic approaches and techniques.

In the following study, I will quickly repeat the basics and then describe the new theories concerning the fibrous skeleton of the heart, basing on anatomical and embryological facts and illustrated with images of the aforementioned preparations and others.
Subsequently, I will describe the osteopathic approaches of the new techniques and try to sum up the holistic interconnections.

I hope that the following sections will help render the innermost core of the heart and its potential "palpable".

4. Anatomical and physiological facts

This section of my study is not intended to replace other textbooks, but simply give an overview (based mainly on Benninghoff A. and Sieglbauer A.). The following is a summary of probably well-known facts to call them up from memory, as well as rather detailed descriptions that are necessary for the understanding of this work.

Form and position of the heart

The heart is about the size of a fist of the respective individual and has a weight of about 300 g. It is covered with myocardium, and its right and left sides are embedded in the mediastinum in the soft lungs. 2/3 lie to the left, 1/3 to the right of the median axis.
The changing shape of this hollow viscus is often described as cone-like, with the rounded-off tip pointing in a caudal direction, whereas the broad basis serves as a cranial outlet for the major vessels (coronary, aorta, pulmonary trunk, inferior and superior cava, 4 pulmonary veins), on which the heart, able to move in its pericardium, is suspended. The two major arterial branches lie in a ventral and median position, the venous branches and the atria lie dorsally. The pulmonary trunk, lying ventrally of the aorta and to the left of the sternum, takes a right curve around the ascending part of the aorta and takes an almost horizontal course against the posterior mediastinum. The aorta, on the other hand, rises towards the right and, behind the sternal angle, crosses transversally to the left in the aortic arch.
Within the chest, the heart is dipped in all three spatial directions. Relative to the sagittal plane, its longitudinal axis is dipped by about 40° from cranial and dorsal to a caudal and ventral direction. In the frontal plane, the same amount of inclination dips the heart from the upper right to the lower left side. In addition to that, the heart is turned around its long axis in a way to make the right chamber sit more ventrally and the left more dorsally.

To the left of the median axis we find the left chamber, a major part of the right chamber with the pulmonary trunk, the left auricle and the adjacent part of the left atrium. To the right of the median axis lie the right atrium and the vena cava. The left atrium takes the most dorsal position; its back wall is dented by the esophagus. The right ventricle has the most ventral position, its brim lies as a border between sternum and diaphragm. The apex itself, covered by the lingula of the left lung, does not touch the pectoral wall.

Thus, we can discern three borders of the heart that are embedded between the two lungs, the sternum, the esophagus and the diaphragm: the frontal, convex sternocostal surface, the lower, plane and slightly concave diaphragmatic surface, and a left surface that nestles convexly against the left lung and constitutes the transition between the sternocostal and diaphragmatic surface (it is therefore also called margo obtusus).

On the outside, the heart cone shows grooves that are a result of the internal septation. The coronary sulcus (atrioventricular sulcus), a transverse groove separating atria and chambers, is uncovered on the backside, whereas in the front it runs beneath the auricula and the pulmonary trunk and aorta. The interventricular sulcus (longitudinal groove in the front and back), commences in the front at the pulmonary artery. Separating the left from the right ventricle, its course leads down and to the left (the apex is part of the left ventricle), to take the inverse course up again in the back.

Projections of the heart:

These points of reference are very clear, however, due to the position and the change of the heart's shape with breathing and heartbeat, they should be taken with a grain of salt. Upper limit: 2nd intercostal space, lower limit: diaphragm, right border 2-3 cm to the right of the sternum's side, the back border is determined by the apex beat. The length of the heart, as projected against the spine, is spinous processes Th5 - Th9; the pulmonary valve lies behind the sternum and the 3rd rib on the left, the aortic valve lies inferior and to the right of the pulmonary valve, the tricuspid valve behind the fourth rib somewhat inferior and to the right, and the mitral valve behind the left half of the sternum to the right and under the level of the fourth rib.

The 4 internal cavities of the heart and the valves

The right atrium, an almost cuboid space taking in the venous blood from the lower and upper half of the body as well as from the heart itself, lies due to the transverse position of the interatrial septum not only to the right, but also anterior to the left atrium and also extends in a caudal direction.

It is situated in an anterior position of the right lung, separated by pleura and pericardium, laterally of the hilus of the right lung, separated by pleura, pericardium and phrenic nerve, posteriorly and to the left of the left atrium and posteriorly and to the right of the right pulmonary veins. Medially, it is close to the ascending part of the aorta and to the pulmonary trunk.

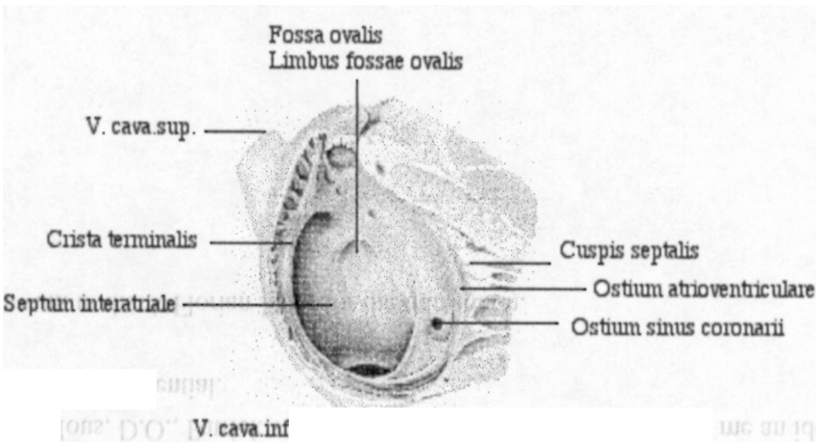


Fig. I. Right atrium in diastole

The inner look reflects the origin from two diverse structures that are separated by the terminal crest, which consists of endocardium. On the one side the actual atrium, which includes a large number of muscle strands (mm. pectinati) and which is attached to the right auricle, which in turn surrounds the ascending part of the aorta. On the other side the very smooth-walled connecting piece of the two venae cavae (originated from the sinus venosus). The right sinus valve of the embryo develops into two new valves, one of which covers the inferior vena cava (caval valve), the other covering the inflow mouth of the coronary sinus, which receives the major veins of the myocardiac wall. In addition to these veins, tenuous cardiac veins with minute mouths end in the right atrium. Within the interatrial septum, a limbus constitutes the brim of the fossa ovalis, the latter being an equivalent of the embryonic foramen that has been closed up by two adjacent septa.

The right chamber has the form of a three-sided pyramid. Its anterosuperior convex surface borders almost directly on the pectoral wall, in most places only separated by the pericardium (a small portion is also separated by pleura and left lung). The plane, slightly concave and caudal surface rests on the diaphragm as on a saddle, and is separated from the left ventricle by the frontal interventricular septum, which is helically twisted and concavely dented, since the right ventricle lies around the left one like a cup.

The inner architecture is characterized by the route of the inflowing blood, leading from the right atrium over the tricuspid valve as well as from the outflowing duct, leading the blood around an angle of about 60° via the pulmonary valve to the lungs. These two ducts are separated by the superventricular crest, which is a thick muscular arch that protrudes to the front and to the right, taking the course from the interventricular septum transversally to the anterolateral ventricular wall. The inflow section is rich in muscular trabeculae and papillary muscles, the latter contracting the tricuspid valve. The anterior papillary muscle (m. papillaris anterior) is the biggest. It sets out from the septomarginal trabeculae, an arch-like muscular trabecula between the ventricular septum and the outer wall, containing the moderator band of the cardiac conduction system. The outflowing part is smooth.

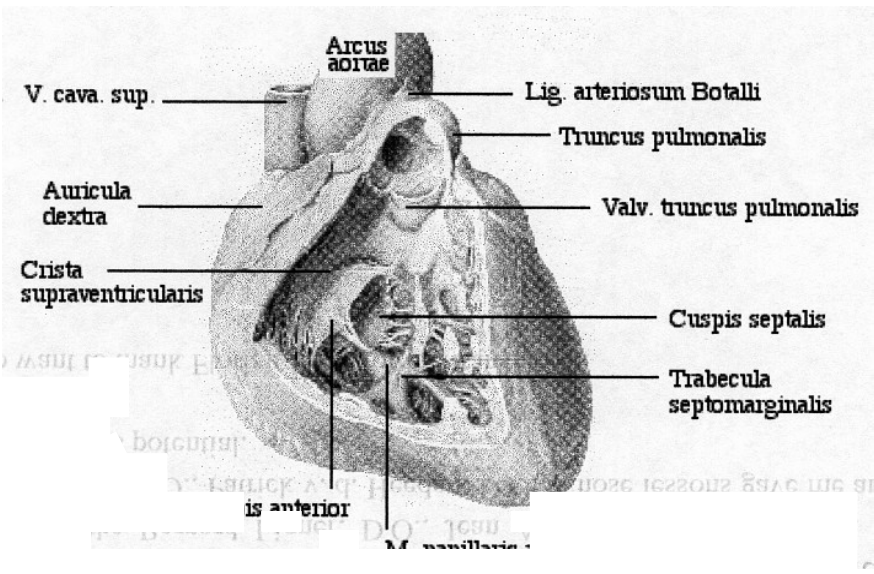


Fig. II. Right ventricle (ventral aspect)

The tricuspid valve is, just like the mitral valve, an atrioventricular valve. It holds an almost vertical position, dipped by about 45° in relation to the sagittal plane, so that it faces the lower anterolateral left side.

It consists of the coronary tendon, which holds three vela. The free ends of the vela are connected to the tips of the conical papillary muscles by means of tendinous cords (refer to "anatomical substratums of the fibrous skeleton").

Of the three vela, the anterior, posterior and septal cusp, the anterior cusp is the biggest, the septal cusp the smallest. The vela are segmented by three incisions, the so-called comissures (anteroseptal, posteroseptal, anteroposterior).

The tendinous cords are whitish, fibrous, collagenous cords, threads that usually depart from the tips of the papillary muscle cones and are attached around the vela. There are five kinds of tendinous cords: cords with a trunk that branches out towards its end, cords with a trunk that branches out into three strands right after the beginning with the strands attached to the velum in different areas, another kind that is long and thin and attached in the brim area of the velum, another that attaches deeper within the velum, and finally cords that are morphologically completely different, originating directly within the ventricular wall and attaching to the basal zone of the vela.

The papillary muscles of the right ventricle can be divided into anterior, posterior, and an irregular group of septal muscles. The biggest, the anterior papillary muscle, originates in the right anterolateral ventricular wall and fuses with the septomarginal trabecula. The tendinous cords that grow from its singular, sometimes bifid, tip attach to the anterior and posterior cusp. The posterior papillary muscle, originating in the ventriculoseptal myocardium, is often bifid or trifid. Its cords attach to the posterior and septal cusp. (Benninghoff; 1985)

The pulmonary valve is, just like the aortic valve, a flap valve. It lies somewhat higher than the infundibulum and separated from the other three valves.

It consists of three semilunar valves that are attached to the annulus. Over the arcs, the walls of the vessel are dilated, which leads to the forming of sinuses. (refer to "anatomical substratums of the fibrous skeleton").

The cuboidal left atrium lies behind the right atrium, separated by the transverse interatrial septum. It is connected with its atrioventricular opening to the left ventricle anterior, inferior and on the left and forms with its posterior part the biggest portion of the base of the heart. The left auricle, pointing towards the left front, covers the pulmonary trunk.
The inner look is characterized by the incorporation of the four pulmonary veins during its development, two of them leading valveless and posterolaterally into the smooth-walled atrium, together with small veins belonging to the heart. The auricle has a few small pectinate muscles.

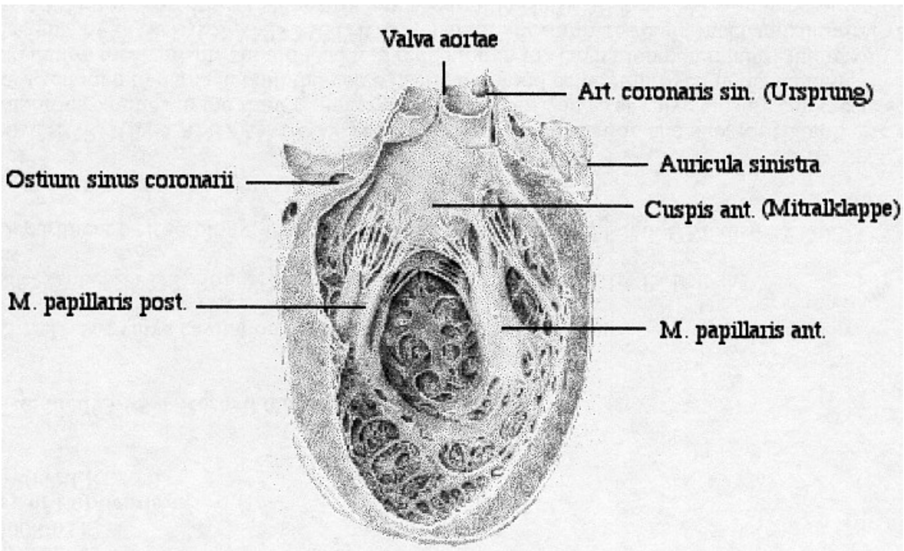


Fig. III. Left atrium and ventricle (view from lateral left side)

The left ventricle has thick walls due to the high arterial pressure proper to the pulse. It forms part of the sternocostal, left, diaphragmal surface of the heart and reaches from the ventricular base up to the apex, its long axis pointing forward, down and to the left.
On the inside, we find an inflow and an outflow section, very close together and separated by the subaortal curtain (intervalvular septum), which is a subvalvular continuation of

connective tissue, and by the anterior cusp of the mitral valve. The arterial blood flow changes direction in an angle of about 10°.
The anterolateral wall of the left ventricle is formed by the interventricular septum, which takes a concave bend into the left chamber, the septum itself being mostly thick and muscular. Closer to the aortic valve, the interventricular wall becomes thinner and consists of collagenous fibers. This membranous part of the septum is an oval surface that, lying under the aortic valve, is partly confluent with the fibrous part of the anterior (right coronary) and the right posterior (non-coronary) flap valves. The inflow section is rich in trabeculae of the variations mentioned above, whereas the outflow section gets increasingly fibrous in its subendocardial tissue towards the end, decreasing the myocardiac portion, and seeming rather smooth.

The mitral valve, the second atrioventricular valve on the atrioventricular transition, is similar to the valve of the right heart in its setup. Its diameter is very variable, but smaller than the other's. It is situated on the same level and faces the apex of the heart.
In this case, also, the ring of the mitral valve is not just a circumferent, fibrous ring (refer to "anatomical substratums of the fibrous skeleton").
The mitral valve has one velum at the front and one at the back.
The multitude of tendinous cords corresponds to the one we found in the tricuspid valve; two very thick cords that originate directly in the tips of the papillary muscles and attach in the closing area of the valve are worth mentioning in this context.
The cords of these two long, finger-like papillary muscles insert in both vela. The anterior muscle (anterolaterale) originates in the sternocostal, mural myocardium, the posterior muscle (posteromediale) in the diaphragmal ventricular wall.

The build of the **aortic valve** is similar to the pulmonary valves. It faces the superior right side and slightly forwards, its position is anterosuperior and somewhat to the right of the mitral valve (for a detailed description of the annulus refer to "anatomical substratums of the fibrous skeleton").

The heart's structure in detail

The walls of the atria as well as of the ventricles consist of three layers. The outside consists of serous epicardium, the middle layer of muscular mass, the myocardium, and the innermost layer of the endocardium that is typical for the intimae of vessels.

The epicardium is the inner, visceral layer of the pericardial sac. It is grown tightly onto the heart and builds a perfectly smooth coating. It consists of mesothelium that sits directly on a thin, fibroelastic layer. At the places of insertion, it merges directly into the outer layer, covering the beginning of the vessels that connect to the corona. Under the epicardium lies the subepicardial fat tissue that is connected with the interstitial connective tissue of the myocardium. It smooths out uneven places and covers the coronary and interventricular sulcus with a thicker and protective layer, just like the nutritive vessels of the heart, nerves, ganglia, lymphatic ducts and lymph nodes. Epicardium and subepicardiac tissue are provided for by tenuous branches of the coronary arteries.

The myocardium varies in thickness throughout the various parts of the heart. It consists of fibers of a special form of striped muscle, similar to the skeletal muscles. However, the muscles of the myocardium form, in addition to a central nucleus, an acute-angled network (the cells touch each other transversally: intercalated disks), the fissures of which are filled with vessel-bearing connective tissue. This tissue separates the interlaced cardiac muscles in strands (a secondary network); such bigger strands are furthermore covered by connective tissue membranes that also hold elastic fibers. The order of the macroscopically more coarse strands seems to reflect the functional structure of the myocardium, the fibers appear as a solidified echo of the original movements. (refer to Schwenk T.; 1995).

In general, it is possible to distinguish three layers of ventricular muscle, similar to the other hollow visci. The outer, longitudinal layer originates at the entire circumference of the coronary sulcus from the fibrous anuli and leads, steeper on the left than on the right, in counterclockwise, screwlike turns towards the apex of the heart. In the vortex cordis, it turns around and rises as an inner longitudinal layer in a clockwise turning motion to streak through the interventricular septum and, going deep into the entire cardiac wall, it joins the annular layer that also originates in the annuli fibrosi. The annular layer, on the other hand, sends fibers into the internal longitudinal layer and the ventricular septum itself. Superficial annular fibers surround both ventricles, deeper layers surround each chamber by taking a plane turn into the septum, and superficial as well as deep fiber loops surround the arterial and venous openings. (refer to Sieglbauer; 1940)

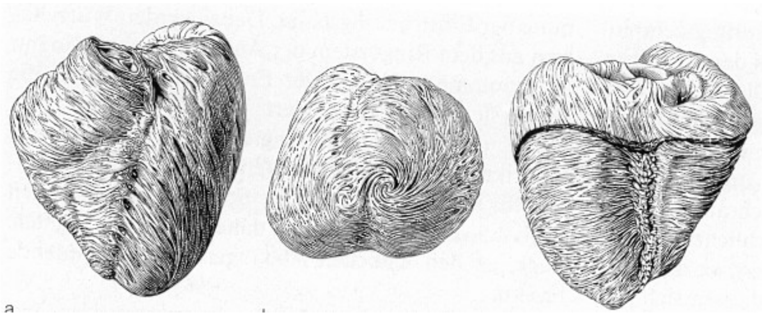


Fig. IV. Myocardium a

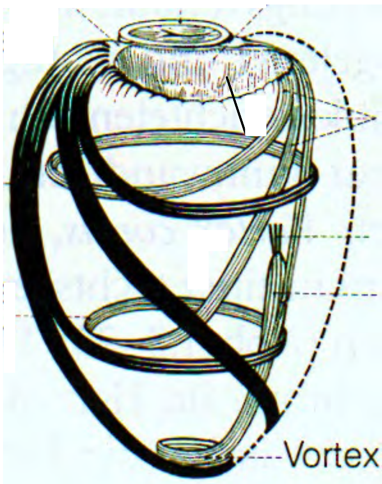


Fig. V. Myocardium b

The by far lesser developed atrial muscles show outer, horizontal fiber strands that connect the two atria, and others that go from the front to the back of the atrial roofs and, just as above, form loops around the openings.

The endocardium consists of an endothelial layer and sits on a layer of connective tissue comprising elastic fibers (to avoid pleating) and fibers of smooth muscle. The subendocardial connective tissue that lies under the endocardium and comprises vessels, nerves and endings of the conduction system and is related to the interstitial connective tissue of the myocardium does not extend to the papillary muscles and tendinous cords.

The fibrous skeleton of the heart

I want to mention at this point that all dense points of connective tissue that surrounds all openings (coronary tendons) as well as areas in which fibrous rings connect, and further the membranous part of the interventricular septum, are called skeleton of the heart.
For further, detailed discussion and description please refer to the later chapter „the fibrous skleleton of the heart“.

The cardiac conduction system

Specific muscle fibers of the myocardium that differ in build (richer in glycogen, less fibrils) and function considerably from the working myocardium are defined from a functional point of view as an entity called systema conducens cordis (cardiac conduction system). They join in a superficial layer, sometimes to form radial bands, and are characterized by the ability of creating and conducting spontaneous, rhythmic excitation.

The sinus node (sinuatrial node, Keith-Flack's node) is spindle-shaped and of no clear outer silhouette. Its size is about 1.0 x 0.3 cm and it is situated right next to the onflow duct of the superior cava into the right atrium, subepicardially in the angle between the infundibulum of the cava and the right auricle, longitudinally to the terminal crest and extending towards the lower vena cava. The sinus node is closely connected to the atrial muscles, sometimes even to the point of becoming undiscernible. It consists of criss-crossing, indistinctly striped muscle fibers and is supplied by its own arterial branch. The sinus node is the pacemaker of the heart's activity, delivering about 60 - 80 impulses per minute under regular conditions, which are transmitted via thin strands to the working myocardium of the right and left atrium.

On the right side of the interatrial septum, between the mouth of the coronary sinus and the attachment point of the septal velum of the tricuspid valve, just above the right fibrous trigone of the heart, there is another node (0.2 - 0.4 x 0.5 cm) of specific fibers that is called atrioventricular node (AV-node, Aschoff's node, Aschoff-Tawara's node). Even under the microscope, it is not always possible to tell this node apart from the surrounding tissue, either.

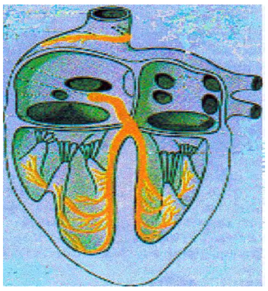


Fig. VI. Conduction system

The continuation of this node is called His' band (atrioventricular band, ventriculonector). The trunk of this bundle (truncus fasciculi atrioventricularis) is up to 0.4 cm thick and 0.5 cm long and intersperses the right fibrous trigone, consisting of connective tissue, towards the ventricle and thus constitutes the only connection consisting of muscle fibers between the atrial and the ventricular myocardium. On the side of the ventricles, it reaches somewhat to the right of the membranous septum the muscular part of the interventricular septum. Sitting on the latter and pulling somewhat towards the front, it then splits into two branches.

The right branch (crus dextrum) has a roundish diameter of about 0.1 - 0.2 cm. It maintains its route towards the front for a little bit after the left crus branches off, then, at the right ventricular septum, under the attachment point of the septal tricuspid velum and behind the septal papillary muscle, it takes a downward bend, hidden in the muscle and separated by a connective tissue tunic and an area conaining lymphatic vessels, to meet the anterior papillary muscle. At this point, some fibers join the working myocardium. The most peripheral of these fibers are thicker and larger than the other myocardiac fibers, they are called Purkinje's fibers. Other fibers take the way back up the interior walls towards the base of the heart, and a small strand reaches the lower section of the pulmonary outflow tract.

The left branch takes the way between the back and the right flap of the aortic valve to reach the left side of the descending ventricular septum, where it branches out like a fan. Usually in two main bundles, it descends to the front and back papillary muscle to fan out in Purkinje's fibers, similarly to the right branch.

The whole bundle of His (trunk and branches) is rich with nerve fibers and ganglia; the feeding of the vessels is done via branches of the septum vessels.

The cardiac vessels

The nutritive supply of the heart is ensured by the coronary arteries (coronary vessels), which build a superficial network from which a large number of smaller vessels branch off into the depth. Originating in the aorta and equipped with an extra thick intima and numerous muscle fibers running longitudinally, these vessels must be qualified as end branches in spite of numerous anastomoses. About 80% of the bigger branches have the same lumen, but sometimes either the right or the left coronary artery takes over more of the nutritive functions than the other. Arteries as well as veins run in the natural grooves of the heart.

The short trunk of the left coronary artery, which originates in the aortic sinus (sinus of Valsalva) above the left flap valve comes forwards, embedded in fat tissue, from behind the pulmonary and between the latter and the left auricle, before it divides into two branches within the subepicardial fat tissue. One of the branches, the circumflex branch of the left coronary artery, reaches the diaphragmatic surface of the heart by following the coronary sulcus and bending the obtuse margin, while the other, the interventricular anterior branch, follows the frontal longitudinal sulcus towards the apex of the heart.

The right coronary artery originates in the right aortic sinus and takes a course between pulmonary cone and right auricle towards the back, following the sulcus coronarius up to the posterior interventricular sulcus, where it turns towards the apex of the heart and becomes the posterior interventricular branch.

The cardiac veins are almost throughout valveless, limiting the valves to the great orifices. Their courses are similar to those of the arteries.

The anterior interventricular branch originates at the apex of the heart and ascends together with the artery to the coronary sulcus to join the great cardiac vein (vena magna cordis), which, taking a left turn in the coronary sulcus, flows into the coronary sinus. The coronary sinus is situated dorsally of the left heart within the sulcus and flows into the right atrium (valve of the coronary sinus). It is 3-5cm long and the greatest passing point of venous blood next to the heart, collecting the venous blood of all major cardiac veins.

(posterior vein of left ventricle, oblique vein of left atrium, middle cardiac vein, small cardiac vein).

A third of the venous blood finds another way: the anterior cardiac veins arrive from the right ventricle and flow directly into the right atrium, and there are minute veins (venae cordis minimae) that flow into the right and left atrium and even into the ventricles themselves via thebesian foramina. The blood from these veins reaches the heart primarily at the base of the papillary muscles and near the apex.

The lymph-vascular system of the heart is subdivided into an endo-, myo- and subepicardiac section and reaches all areas of the heart. The capillaries that are situated between the fibers of the myocardium join to form small vessels that for the most part follow the course of the blood vessels. The lymph drainage is done via bigger lymph vessels that originate in the subepicardial network. They reach the ventral surface of aorta and pulmonary along the coronary sulcus and anastomose at this point. The walls of the major vessels are accompanied by lymph vessels with the possibility of embedded lymph nodes. These vessels finally penetrate the pericardium and reach, ventrally of the bifurcation of the trachea, the frontal mediastinal lymph node as their primary goal.

The nerves of the heart

The nerves of the heart, originating in the sympathetic, parasympathetic, and, partially, the phrenic nerve, possess autonomously efferential as well as viscerosensitive afferential fibers. Right next to the heart, they form an intricately interlaced network, the cardiac plexus. Strands of this plexus penetrate the wall of the heart, surrounding working myocardium and the cardiac conduction system with fine threads and ending in tenuous norardrenergic and peptidergic fibers.

The upper part of the cardiac plexus assumes a superficial and ventral position and contains mostly fibers from the left cardiac nerves, while the great cardiac plexus has a deeper position and contains fibers from both sides. Its branches follow the coronary sulcus as right and left coronary plexus, along the coronaries, and on the other hand the groove between superior cava and superior right pulmonary vein to the back wall of the atria. The lacework of the cardiac plexus is permeated with nerve cells that build small ganglia (cardiac ganglion, aortic paraganglion, supracardiac bodies). These ganglia reach from the front side of the aortic arch to the arterial ligament.

Three major branches originate in the parasympathic nerve, all of which head towards the cardiac plexus: The superior cardiac nerve originates at the caudal brim of the inferior cervical ganglion and, dorsally of the common carotid artery, continues in a caudal direction, the middle cardiac nerve that originates in the medium cervical ganglion and soon joins the superior cardiac nerve, and finally the inferior cardiac nerve that originates in the inferior cervical ganglion and the upper thoracic ganglia. They all carry postganglionic, autonomous fibers, the preganglionic fibers of which stem mostly from Th1 - Th4. They act by increasing the catecholamine release, thereby speeding up the heart rate, increasing the systolic power and shortening the atrioventricular transmission time (positive chronotropic, inotropic and dromotropic).

The parasympathic fibers of the heart stem from the vagus nerve, which extends 2-3 branches right below the nodular ganglion already, the superior cervical cardiac branches that grow along the medial border of the neck vessel strand and extend fibers to the thyroid plexus and other near vegetative nodes before penetrating the cardiac plexus. Other branches of the vagus branch off in the pectoral section, in the middle of the vagus as middle cardiac branches, and in the section where the recurrent laryngeal nerve takes the bend as inferior cardiac branches. They all contain efferential parasympathetic fibers from the encephalic trunk and viscerosensitive fibers with their cell bodies in the nodular ganglion and the jugular ganglion. They effect an increased release of acetylcholine, thus slowing down the heart rate (the fibers from the right vagus go primarily from the cardiac plexus to the right atrium) and prolong the transmission time (the fibers of the left vagus go primarily to the AV-node) (negative chronotropic and dromotropic).

The pericardium

The heart sac (pericardium) is a serous sac that serves as a gliding sheath for the heart and avoids its overextension. It consists of the epicardium (described above), the inner visceral layer and the outer parietal layer, the latter being fortified by a fibrous layer rich in collagen to form a strong skin.

This fortified parietal layer is most developed over the parts of the heart that contain less muscular tissue than the rest. Its frontal right part is grown together with the trefoil tendon of the diaphragm and connected to the parietal pleura on the side and, by means of fortified strands of connective tissue, movably attached to the spine (Lig. vertebropericardiacum), to the sternum (sternopericardiac ligaments) and to the trachea (fascia bronchopericardiaca) (refer to Toldt; 1911).

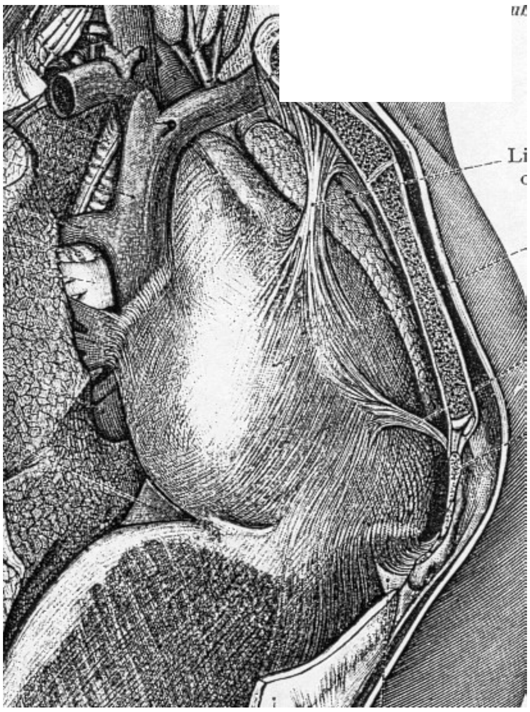


Fig. VII. Pericardium; lig. Sternopericardiacum inf. et sup.;

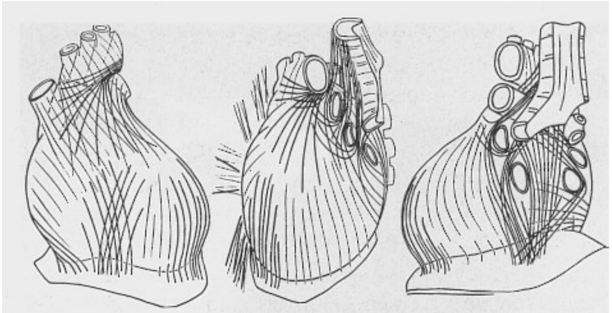


Fig. VIII. Pericardium; connective tissue fascicles, direction of the fibers

The reflection are of the pericardium into the parietal layer surrounds aorta and pulmonalis in the front, both of which run about 3 cm within the pericardium. In the back, they cover the atrial veins with reflections that are buildt in such an intricate manner as to form recesses and sinus; the larger of these sinus are the transverse sinus of the pericardium, separating the venous from the arterial part, and the oblique sinus of the pericardium, which is situated between the left and right pulmonary veins.

The mesothelium layer of the serous tunics of both pericardial layers produces small amounts of an amber-colored liquid that reduces the friction in the space in between.

The blood supply of the outer layer is taken care of by the pericardiophrenic artery, originating from the internal thoracic artery, and by pericardiac branches of the superior phrenic arteries: the venous blood is supplied via the pericardiac veins and the brachiocephalic vein. The inner layer, on the other hand, is supplied with blood by the coronary vessels, as mentioned above.

Physiological basics

In this section, I will shortly discuss the essential physiological basics, since they will be crucial for the following concepts. For a more detailed physiological exploration of the topic, please refer to the relevant special literature.

80% of the total blood volume (TBV) of about 5 liters fills the so-called low-pressure system consisting of veins, right heart and vessels of the pulmonary circulation. This system has a mean pressure of 15mmHg (2 kPa) and due to its function, its high capacity and its elasticity, it can also be seen as a blood reservoir. The rest of the blood is taken up by the arterial high pressure system.
The blood volume that is expulsed by the heart in a certain time unit is called cardiac output. It can be calculated from the heart rate times stroke volume, or following the Fick's principle. In a resting position, it is about 5 l/min, distributing among the organs of the major circulation, arranged parallely, in the order of vital necessity and immediate necessity. The minor circulation, on the other hand, is arranged serially and receives the whole cardiac output.

The arterial blood pressure within the systemic circulation lies between a maximum figure (systolic pressure) during the systole of the heart, which is determined by the cardiac activity and the elasticity of the major arterial vessels, and a minimum figure (diastolic pressure) during the cardiac diastole, which is determined by the flowing speed of the blood, in other words, by the total peripheral resistance (TPR). The resting levels are usually about 120/80 mmHg (16/10.7 kPa). The blood supply to the organs is determined by the mean blood pressure that can be calculated graphically.

While the arterial blood pressure depends primarily on cardiac output and TPR, the venous blood pressure is a product of blood volume and capacity of the circulation (in veins close to the heart about 1.5 - 4 mmHg). Low pressures within the vessels leave the diameter of the vessels to be determined of the pressure of the environment. The intrathoracic pressure, highly determined by the breathing, leads to fluctuations in the lumen of the venae cavae, in other words, a pumping action of the breathing on the venous reflux to the heart. (To be a little more precise: the intrathoracic pressure sinks lower than the pressure of the vena cava during inhalation, leading to an extension of the vessel's lumen and to an increase of reflux to the right heart. This leads in turn to a short increase in stroke volume of the right ventricle and of the flow in the pulmonary arteries, while the stroke volume of the left ventricle decreases due to the decrease in blood supply via the extended pulmonary veins (Frank Starling mechanism).

During a single cardiac cycle, i.e. within 1 sec, about 70 times/min as a resting level, the following actions occur: The sinus node discharge takes place during the diastole of the ventricle and leads to a stimulation of the atrial muscles (atrial systole). The latter contract and thereby increase atrial pressure, leading to the expulsion of the blood, completing the filling of the ventricle. This is at the same time the end of the diastole, resulting in an end-diastolic volume of 125 - 250 ml. The continuing electric stimulation now reaches the ventricles and incites their contraction. During the contraction period, all four valves are closed, i.e. while the blood volume remains the same, the pressure increases rapidly (isovolumetric contraction). As soon as the pressure in the left ventricle exceeds at about 80 mmHg the pressure of the aorta, the flap valves open. Now the expulsion phase has started, during which the pressures reach a maximum (120 mmHg). During the following relaxation phase of the ventricles, which makes the pressure sink rapidly below the arterial pressure, the flap valves close and the diastole is initiated. In the meantime, the atria have filled again, due to the suction action of the sinking flap levels during the expulsion phase, and ensure a rapid filling of the ventricles right in the beginning of the filling phase.

5. The embryological development of the heart

Please note that for the understanding of the following study, embryological basics are helpful and even prerequisite. Since imparting the necessary basics is beyond the scope of this study, please refer to the relevant literature (see bibliography).

The circulation system, consisting of blood, blood vessels and heart, is the first functioning organ system of the embryo and keeps changing form and structure even after taking up its activity.

During the third week, the heart develops from a horseshoe-formed cluster of densened mesenchymal tissue, the **cardiogenic mesoderm**, which is situated in front and to the side of the buccopharyngeal membrane. The cardiogenic plate is an element of the splanchnopleure (the celom has developed at that point), but it also receives cells from the neural crest (on one level with the three cranial somites) and from the paraxial mesoderm.

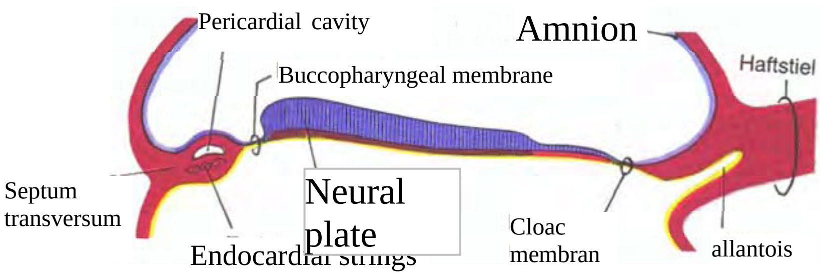


Fig. IX. Human embryo, day 18,
embryonic disc and longitudinal section

Due to the growth of the cranial flexure, the cardiac plate shifts between the 18th and the 22nd day from its initial, rostral position and together with the dorsally adjacent celom fissure to a ventral position, thereby forming a rostrally dead-ended primitive entoderm that constitutes the primordium of the upper part of the foregut. The cardiogenic zone and the pericardiac cavity turn 180° in relation to the embryonic body around a transverse axis at the level of the foregut. (refer to Langman J.; 1985 and Drews, U.; 1993)

The **pericardiac cavity** develops from the cranial section of the celom fissure. It is conceived as an entity from the very beginning and is connected to the celom fissure on the right and left side. (refer to Benninghoff A.;1985).

The **cardiac muscle** itself is a derivative of the splanchnopleure, which becomes thicker in the area of the cardiac primordium (promyocardium), of the pericardiac cavity.

Together with the folding of the embryo from the yolk sac (refer to Moore K.L.; 1990), vesicles build between the primordium of the cardiac muscle and the entoderm of the upper part of the foregut, which are limited by the angioblasts and approach the middle axis, building the unpaired heart tube (proendocardium). In humans, the paired endocardiac tubes that go over the first aortic arch to the dorsal aorta usually don't develop, since the cardiac primordia grow together before the building of tubes (refer to Christ, Wachtler; 1998).

The unpaired heart tube consists of three layers.

On the very inside lies the **endothelial endocardium**, which borders on a loosely structured layer of specialized, extracellular matrix, the **cardiac jelly** (refer to Manasek; 1970). Later, the cardiac jelly is covered by the **myocardium**, which is in turn covered by **epicardium** that stems from the serous epithelium adjacent to the sinus venosus. In this state, this is called primitive heart tube (refer to Larsen W.J.; 1997)

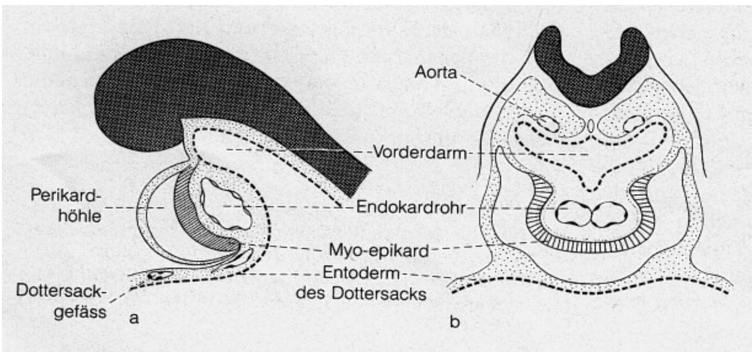


Fig. X. Development of the heart

The heart tube, which is already primitively segmented along its axis, continues together with the descensus of the intestinal aperture in a craniocaudal direction. At that point, the heart tube and the frontal diameter of the pharynx are connected for some time via the dorsal mesocardium.

The development of the straight, tubular heart, initially consisting of a bilaterally symmetrically unpaired heart tube developed by fusion of paired cardiac primordium, is completed on the 20th day at a size of about 1 mm.

On the 21st day, the heart tube starts to bend to form a loop pointing in a ventral and right direction (the apex of the heart will point left after the increase in size of the left ventricle), thereby forming the first asymmetrical structure of the body.

The result of this **cardiac looping** is an S-shaped cardiac primordium, whose inflow conduit, originally in a caudal position, now lies dorsally in relation to the outflow conduit (which we called bulbus cordis above) and leads to the atrium, which at this point is followed by the ventricular part of the cardiac primordium.What has been bulbus cordis so far is now separated into conus arteriosus, situated next to the ventricle, and truncus arteriosus, which is situated in a distal position.

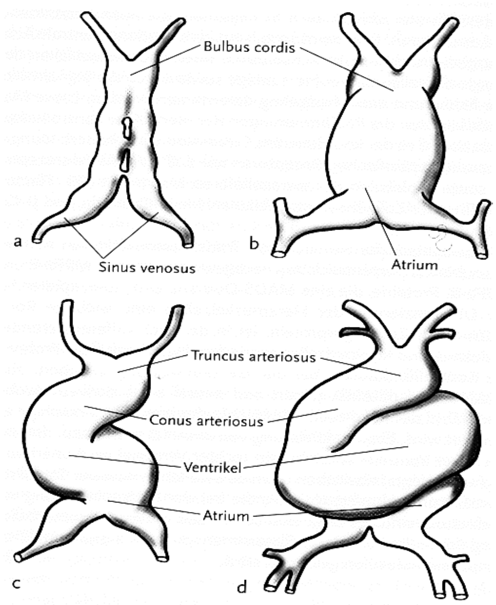


Fig. XI. Cardiac looping, day 20 - 25

On the 21st day after the conception, the cardiac primordium, consisting of already differentiated myocytes, starts beating wavelike and as yet undirected. The unidirectional circulation starts at the end of the 4th week. (refer to England, M.A.; 1996)

The ensuing partition of the heart, taking place between the 27th and the 37th day at a simultaneous longitudinal growth from 5 to about 17 mm is brought about by mesenchymal cells. The latter grow into the rather wide cardiac jelly (myocardiac basement membrane) and thereby form the **endocardiac cushions**, which in turn separate the atrial from the ventricular section.

This creates the **atrioventricular canal**, which grows slower than the atrial and ventricular section.

Further endocardiac thickenings are created on the contact surface between ventricular section and outflow tract.

One dorsal and one ventral cushion as well as two smaller lateral cushions (cardiac cushions) form within the atrioventricular canal, which grow into one another and fuse to separate the atrioventricular canal into a right and a left section. The endothelial mesenchyma that has grown into the endocardiac cushions condenses to dense connective tissue.

Within the outflow conduit, two endocardiac cushions (valvular ridges) build as well, to develop later into parts of the semilunar valves.

From the roof of the hitherto uniform atrium, a semilunar septum (**septum primum**) starts to grow in the fifth week, separating the atrium into a right and a left section.

The concave, caudal brim of the septum primum constitutes the border of the foramen primum, which gets increasingly smaller and finally closes up entirely as the septum primum grows together with the endocardiac cushions.

Perforations that appear in the foramen primum before it closes up lead to the building of the foramen secundum within the fifth week, through which blood streams from the right to the left atrium and which persists during the fetal period as part of the **foramen ovale**.

Towards the end of the second month, the septum secundum develops to the right of the septum primum, growing curtainlike towards the base of the heart. This connection between right and left atrium is delimited by the sickleform free brim of the septum secundum and by the septum primum and is called foramen ovale.

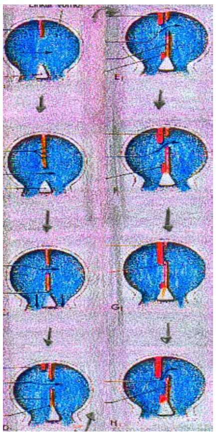


Fig. XII. Septation of the atria

During the further development, the septum secundum overlaps the foramen secundum, making the caudal section of the septum primum act as a valve that lets the blood stream unimpededly from the right to the left side.
Only after the birth, the increased pressure presses the septum primum within the left atrium against the septum secundum, thereby finally separating the atria. (The septum primum forms the basis of the fossa ovalis that must yet develop, whereas the limbus fossae ovalis is formed by the free brim of the septum secundum.)

The unpaired end section of the venous inflow conduit of the heart, the **sinus venosus**, leads at first into the middle of the as yet common atrium. After the cardiac loop has developed and the atrium has been septated, the mouth moves to the right side, while the right sinus horn (the joint part of umbilical vein, cardinal vein and yolk sac vein) increases its size and is integrated into the wall of the right atrium.
Later, the border between sinus and atrium will be made visible on the outside of the heart by the terminal sulcus and on the inside by the terminal crest.

The left sinus horn becomes the coronary sinus.

The chambers are septated by the ventricular septum, **septum ventriculi**, which consists of a muscular and a membranous part.
The muscular part develops on the borderline between ascending and descending ventricular branches on the bottom of the ventricular loop, at the point where the surface of the heart is marked by the interventricular groove, by folding up and out of the parietal myocardium.

The short back and the longer frontal branch of the horseshoe-shaped septum that grows into the lumen of the chamber grow together with the endocardiac cushion of the atrioventricular canal, initially leaving a connection in the form of the foramen interventriculare.

This foramen is closed up within the seventh week by the membranous part of the interventricular septum The latter is made up of connective tissue from the endocardiac cushions, of further growth of the muscular septum and of the proximal part of the truncus cushions, which septate the outflow tract.

The characteristic **outflow tract** of the heart builds from the not yet subdivided bulbus cordis by integration of its most proximal section of the arterial cone into the chambers.

Two crests build during the fifth week (truncoconal cushions consisting of cells from the neural crest and providing elastic fibers at a later point). They continuously increase in height, take a spiral-like course and finally meet in the middle of the outflow tract where they fuse to form the aorticopulmonary septum.

The spiral-like course, in itself a result of the blood flow, creates two entwined outflow ducts, aorta and pulmonary trunk. (refer to Moore K.L.; 1990).

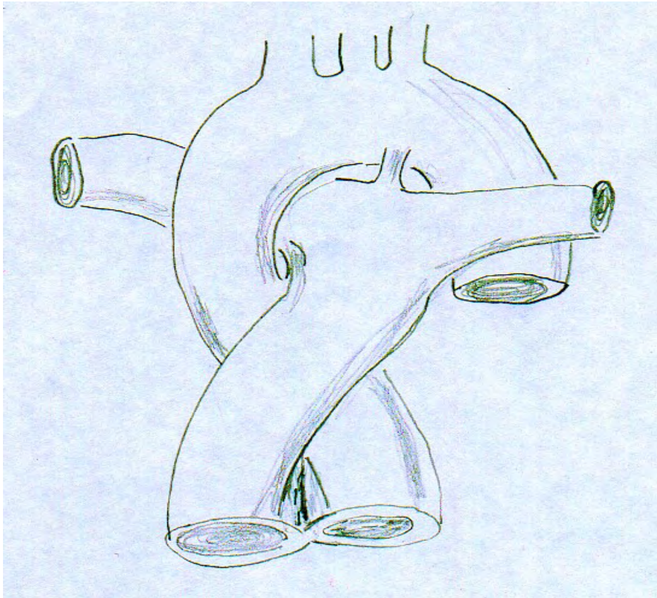


Fig. XII. Division of the outflowtract

The atrioventricular valves build from the endocardiac cushions and the septal and mural chamber walls.

The building of the valves, cords and free parts of the papillary muscles, all of them differentiation products of the originally sponge-like wall of the chamber, is brought about by myocard dying a programmed cell death between the above elements and the final ventricular wall. This is called morphogenetic apoptosis.

The final setup of the valve system isn't completed until after birth.

The **flap valves** build from the two endocardiac cushions and the aorticopulmonary septum.

The valves are somewhat plump at first; they do not attain their final form until the infant's second year.

The cells of the **cardiac conduction system** originate just like the myocardium from the splanchnopleure of the cardiogenic plate, probably with cells from the neural crest involved in the process. (refer to Christ, Wachtler; 1998).
The first cells of this kind can be found in the inner layer of the myocardium, where they are arranged in annular structures next to the atrio- and bulboventricular canal. The cells that become the sinus node, on the other hand, can be found at an early point of time in the caudal inflow duct.

The **blood vessels** of the heart start to build only after the 40^{th} day. Up to this point, the heart is nourished exclusively by diffusion. The building of the blood vessels starts in the ventricular section of the subepicardiac mesenchyma.
The developing vessels join the coronary sinus and the aorta, that is to say, they don't originate in the aorta but develop a link to it (homing).

The **innervation** of the heart develops from three different sources.
In 10 - 13 mm embryos, sympathetic adrenergic fibers that originate in the cervical sympathetic chain ganglia, which are in turn derivatives of the truncal ganglionic crest, reach the sinus venosus.
The ganglion nodosum builds from an ectodermal placode. It is the origin of sensitive fibers reaching the heart via the vagus.
Preganglionic, parasympathetic fibers also reach the heart via the vagus.
The vegetative ganglia in the atrium, in the atrial septum, the coronary sulcus and the interventricular sulcus all originate in the neural crest.

6. The fibrous skeleton of the heart

6.1. The fibrous skeleton of the heart at the center of contemplation

The heart forms between the 19th and the 22nd day of an embryo's life. It is the first organ that has to function while it is still building. It ensures the survival of the embryo.
As every other organ, however, the heart is subjected to shifts of position and changes of form.

The question is, what do those two endothelial tubes need before and after they melt into one and start their contractions? Contractions that are, in the beginning (21st day), still undirected and, similar to the tides, go both directions.

Pouches build, following the moves of the embryo and rotating and being determined by the bloodstream: tissue spreads to calm zones, where the flow is less insistent, and around cavities that fill with blood.
In addition to all that, the newly forming heart needs a guiding structure, something to assist and second its partitioning into separate chambers, something to manifest the direction in which the blood is supposed to flow (refer to Blechschmidt E.; 1989 and Schwenk T.; 1995).
This guiding structure needs to be nimble, since the outer muscle constantly contracts and dilates in its own rhythm.
At the same time, it has to provide strength and structure, being a stabilizing element of the whole.
Nothing but the connective tissue is apt to fulfill all these conditions, which shows that structure and function are in reciprocal relation to one another (refer to Foundations; 1997).

Thus, endocardiac cushions form - who wouldn't like to rest his head on one, like the embryo cuddling against the bulging heart - and help modify the connections between atria, chambers and the major vessels in a way to ensure optimum functionality.

Valves form, letting the blood stream pass or collect (the blood streams into the chambers and, after collecting there, into the major vessels), and these valves are not only enveloped, but also streaked with aforesaid connective tissue and are therefore closely related to their suspension by their constituting materials, also.

The connective tissue does not only fulfill a dynamic task, it also completely separates the muscles of the atria from the chambers and thus provides the basis for the conduction system's function and a continuous protection of the neural tissue.

This connective tissue, the fibrous skeleton of the heart, is at the center of cardiac action.

It provides a - relatively - stable basis for the orientation of ostia and myocardium and is an "intelligent" product of the need for the bloodstream to provide pre- and postnatally an optimum supply at the lowest-possible energy expenditure.
At the same time, it is the sluggish-elastic reflection of a constantly moving organ that is auto-controlled in its movement and contraction.

6.2. The development
of the fibrous skeleton of the heart

In this section, I would like to discuss the development of the fibrous skeleton of the heart in order to, once more, highlight the various structures leading to its development and to illustrate the complexity of the matter with detailed information.

The first to develop is the unpaired heart-tube, which consists of endothelial endocardium, cardiac jelly, myocardium and epicardium. The cardiac jelly is a loose and rather thick layer, an extracellular matrix containing sulfated proteoglycans and the microfibular proteins fibulin and fibrillin. It is also called myocardiac basement membrane (refer to Eisenberg, Markwald; 1995).

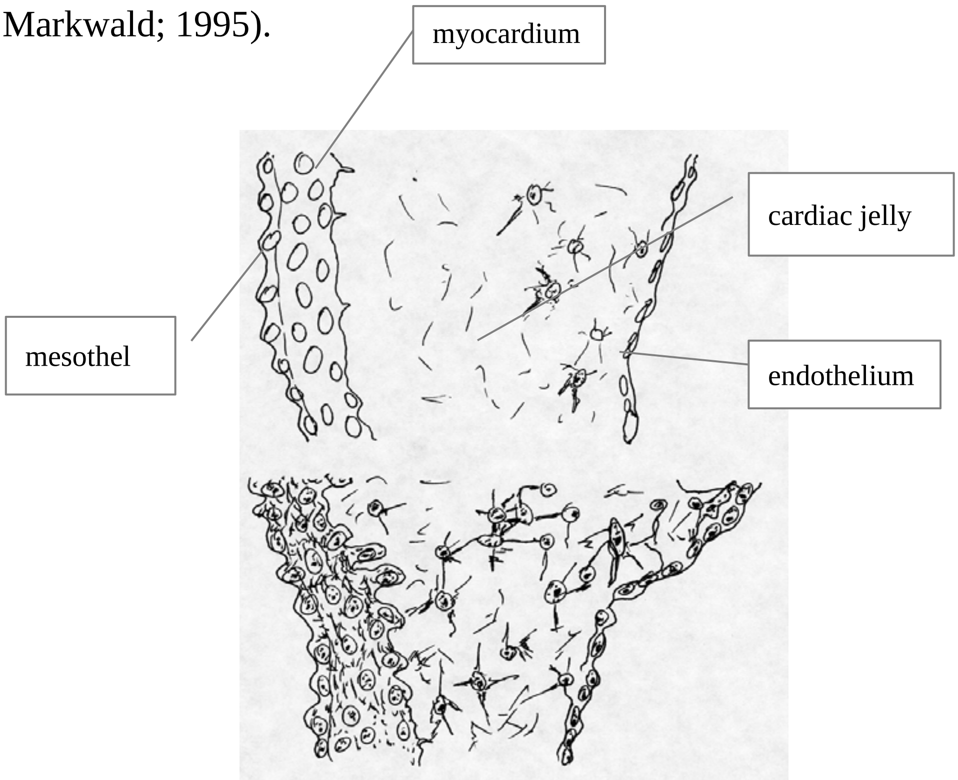


Fig. XIV. Cardiac jelly;
chicken embryo; 33 somites, 41 somites

It is assumed that, during Carnegie stage 14, the selective accumulation of cardiac jelly takes place at the endocardiac aspects of the constriction caused by the atrioventricular sulcus, which can be detected for the first time during Carnegie stage 10 (refer to Magovern; Moore; Hutchins; 1986).

Mesenchymal cells enter the myocardiac basement membrane. These cardiac mesenchymal cells are originally cells of the endocardium that transform into mesenchymal cells. Only cells from two areas are able to perform this endotheliomesenchymal transformation: cells from the atrioventricular canal and from the transitional area between ventricle section and outflow tract.

This is a complex process of molecular biology, necessitating competent endocardiac cells that are able to keep the cell adhesion molecules (NCAM) in check. It further necessitates inductive signals from the myocardium (adherones) and the assistance of a transforming growth factor (TGF-ß3) (refer to Christ, Wachtler; 1998 and Barton P. et al.; 1992 and Fenderson B., et al.; 1993 and Icardo J., Manasek F.; 1984 and Sugi Y., Markwald R.; 1996).
Another regulative task affecting the endotheliomesenchymal transformation is performed by epicardium-derived cells (EPDCs) entering the endocardiac cushions and, after changing to cardiac fibroblasts, participating in the formation of the fibrous skeleton of the heart (refer to Gittenberger-de Groot A., et al.; 1998).

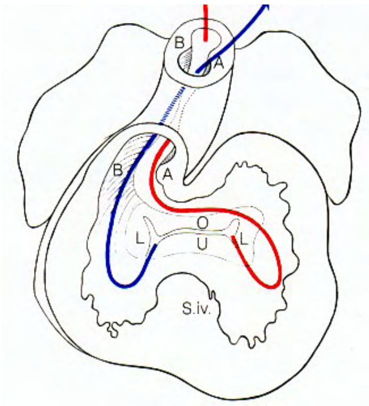
The endocardiac cushions are a result of the cardiac mesenchyma's entering the cardiac jelly: This very migration of the cushion tissue cells entering the cardiac jelly through the heterogeneous extracellular matrix is the central event of the cushions' initial growth (refer to Markwald R., et al.; 1981)

Within the endocardiac cushions (one dorsal and one ventral cushion, two small, lateral ones and two in the outflow duct) the mesenchyma condenses to form a dense connective tissue. Thus, the future position of the fibrous skeleton of the heart is determined.

The next step is a further growth of the endocardiac cushions within the by now rather transverse fissure of the atrioventricular opening. This growth is determined by the blood flow.

We may assume that even at a very early state, the two bloodstreams entering the chambers through the right and the left sinus horn don't mix, but go separate ways. Their flow is determined by the form of the heart-tube and by the direction assigned to each one by the position of the sinus openings. Within the heart, the two blood streams entwine: the pulmonary stream coming from the right atrium winds ventrally around the aortal stream coming from the left atrium.

It is therefore clear that the formation of the heart's septa does not create a new flowing setup, but consolidates the given conditions. Formation and position of the partitions is crucially influenced by hemodynamic factors, since the material of the septa collects most easily on the banks of the two flowing ducts (refer to Benninghoff A.; 1985).



A,B – bulb septa
O,U – endocardial cushions (inf. et sup.)
L – lateral cushions
S.iv – interventricular septum

Fig. XV. 8 mm human embryo, frontal section, setup of the blood flow

It is now obvious that the atrioventricular canal lies at first on a coronary plane between the left side of the primitive atrium and the future left ventricle (refer to Larsen W.J.; 1997).

Due to the growth of the endocardiac cushions, the atrioventricular canal is separated in a left and right section, while at the same time moving to the right (refer to Wenink A., et al.; 1994).

Finally, the endocardiac cushions join around the two openings of the atrioventricular canal, i.e., the mitral and the tricuspid ostium.

They are also the origin of the interatrial and interventricular parts of the septum adjacent to the atrioventricular septum (refer to Cruz de la M., et al.; 1983; Dean J., et al; 1994).

The five vela of the atrioventricular valves build from the endocardiac cushions with the participation of the myocardium (refer to Lamers W., et al.; 1995).

The two septal vela grow from the fusion of the upper and lower cushion, the other three vela from the lateral cushions (refer to Drews, U.; 1993).

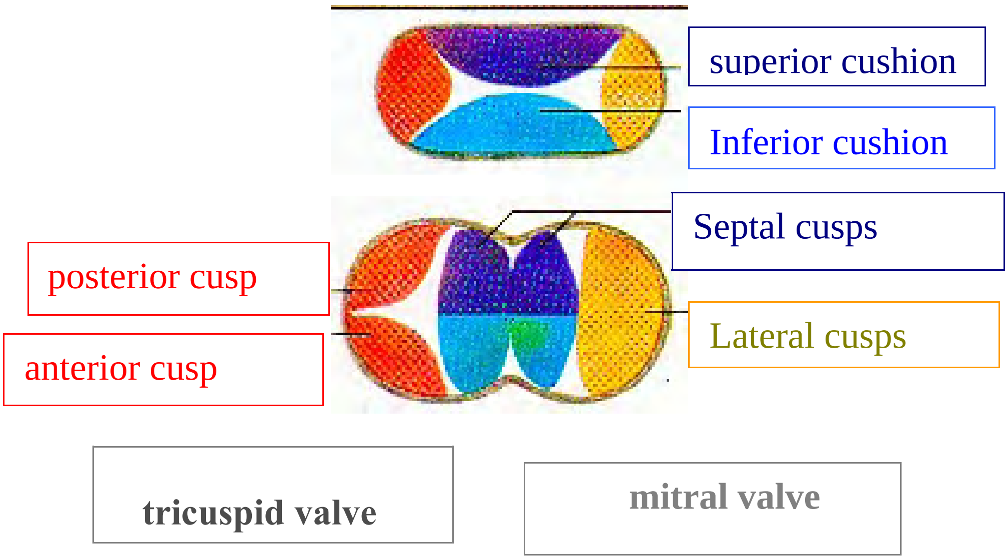


Fig. XVI. Endocardial cushions in the atrioventricular canal

While the atrioventricular valve is still separated from the semilunar valve during Carnegie stage 13, whereas in stages 15 and 17, while the four chambers are building, the aortic valve has rotated into the close vicinity of the atrioventricular valves, and during the stage 19, it fuses with the AV-region (material of the aortic and mitral endocardiac cushion). The ratios and distances that are fixed during stage 19 remain the same hereafter (up to stage 17, the intervalvular distance keeps growing, then it remains practically unchanged). Therefore, we can say that while the left ventricle increases in length to three times its original size, the distance between mitral and aortic valve remains the same (refer to Teal S., et al.; 1986)

The fusion of the endocardiac cushions (on the side of the epicardium) with the tissues of the atrioventricular sulcus (epicardiac side) starts during the 7th week (refer to Wessels A., et al.; 1996). The valves themselves differentiate mainly between the 35th and the 42nd day, at the same time the vertebrae and the bones of the chest start to chondrify and ossify. During this period, both structures may be affected to a similar extent by outside factors (refer to Hurst T.; 1994). Thus, a straight posture of the upper part of the spine, as, e.g., in the straight back syndrome (refer to SBS), coincides with significant frequency with valvular heart diseases, especially in the case of mitral valve prolapse syndrome and bicuspid aortic valve (refer to Ansari A.; 1985).

The closing up of the interventricular foramen through the membranous interventricular septum, which is part of the fibrous skeleton of the heart, is the last step of the septation of the heart. At the upper brim of the septum, the septum primum (in the atrium) meets the skeleton of the heart (in the atrioventricular canal) and the spiral-formed septum (refer to Larsen W.; 1997). During this event, the relative positions are the same as in a fully developed heart (refer to Bartelings M., Gittenberger-de Groot A; 1988).

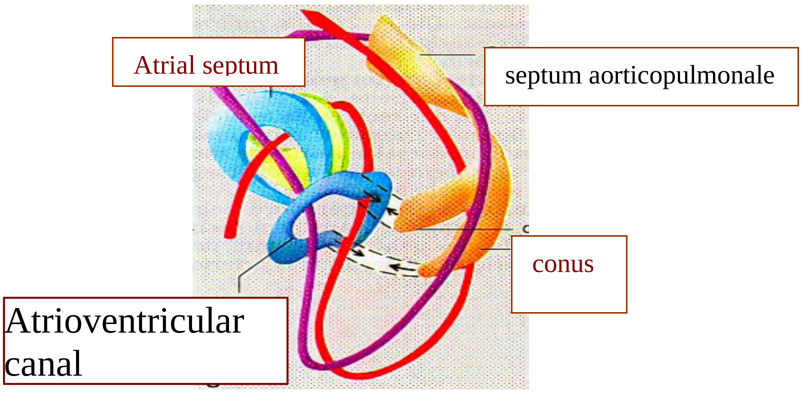


Fig. XVII. Septum aorticopulmonale and septum primum

The tendon of Todaro develops solely from the inferior endocardiac cushion, which might explain possible additional AV-nodes.

It is in contact with the base of the septum secundum (refer to Domenech-Mateu, et al.; 1994).

After the septation of the heart is completed, the development of the fibrous skeleton of the heart is over, too.

The primordium of the atrioventricular conduction system can be detected starting with the Carnegie stage 16 and is the original material of the AV-node and the fascicle of His. It is enveloped in mesenchymal tissue from the endocardiac cushions from the very beginning (refer to Domenech-Mateu J., et al.; 1993).

The position and the axis of the heart remain unchanged during intrauterine life starting with the Carnegie stage 19 (refer to Comstock C.; 1987).
Deviations from the heart's axis (in relation to the position of the thorax) are associated with congenital cardiac diseases (refer to Shipp T., et al.; 1995).

The development of the heart might be directly influenced by neurogenic cells (refer to Climent S., et al.; 1995).
In addition to angioblastic mesenchyma and the epithelium of the splanchnopleure, neural crest cells might be participating in this process. They stem from a region between the otic vesicle and the caudal end of the 3rd somite.
It is a proven fact that neural crest cells participate in the development of endocardiac cushions, of the aorticopulmonary septum and maybe even of the conduction system.

Neural crest cells are cells that leave the neural tube and at the same time lose their epithelium-specific adhesion molecules. Consequently, they develop a new class of adhesion molecules that serve to identify determinants in collagenous matter and in the glycoproteins of the basement membranes (refer to Drews, U.; 1993).
They become neural and neuroglia cells of the spinal ganglia and the vegetative nervous system, sensitive ganglia of the encephalic nerves V, VII, IX, and X, Schwann cells, melanocytes and Merkel's cells, arachnoida and pia, medulloadrenal cells and C-cells of the thyroid gland, and they are part of the ciliary muscles and the muscles of head and dermis.

In experiments with chicken embryos, the existence of NCAM, neural cell adhesion molecules, in the endocardiac cushions could be proved, especially in the endotheliomesenchymally transformed cells within the cushions. The expression of NCAM is regulated regionally in the heart. The expression pattern confirms the assumption that neural crest cells are involved in the differentiation of atrial and ventricular walls, in the fusion of the atrial septum with the endocardiac cushions, in the fusion of the endocardiac cushions themselves and in the formation of the ventricular trabeculae (refer to Burroughs C. et al.; 1991).

Neural crest cells are also and primarily involved in the forming of the aorticopulmonary septum (refer to Sumida H., et al.; 1989).

6.3. The anatomical substratums of the fibrous skeleton of the heart

In this chapter, I will present the fibrous skeleton of the heart in an anatomical approach, describe its elements and illustrate my discourse with figures.

The fibrous skeleton of the heart lies approximately on the same level as the coronary sulcus, i.e., on the level of the ventricular basis. It interacts closely with the atrioventricular openings and their valves as well as with the openings of the arterial outflow tract and its valves. It forms a complex frame consisting of collagen and containing membranous, tendinous and fibroelastic extensions (refer to Williams P.L.; 1995)

All four cardiac valves originate in the same plane: the fibrous skeleton of the heart. The latter constitutes a complicated, shapable, three-dimensional continuum.

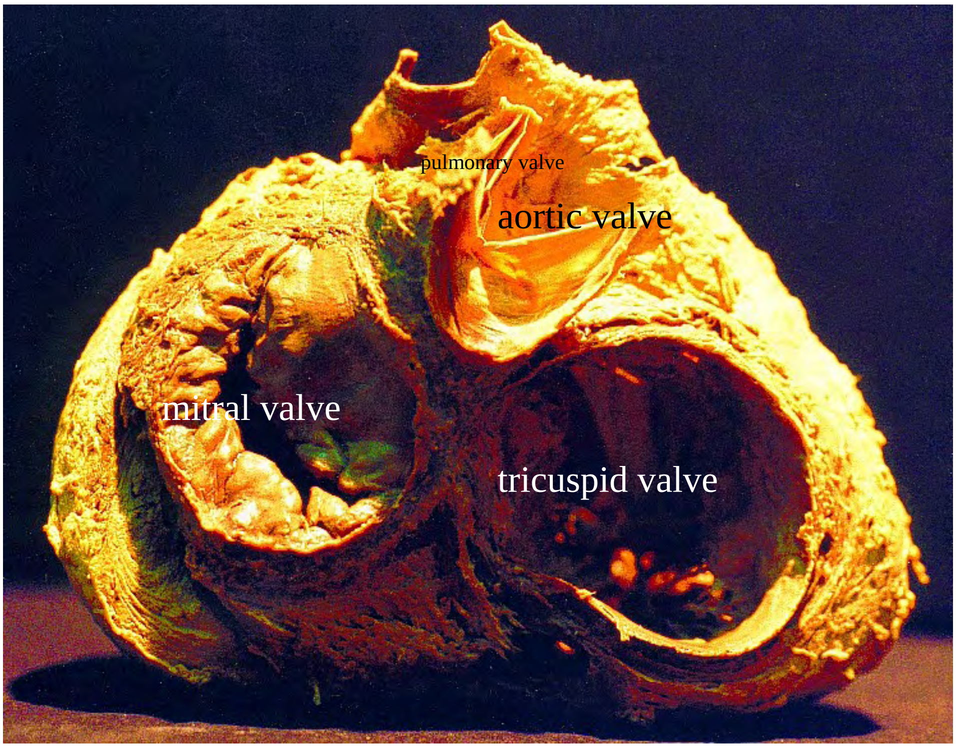
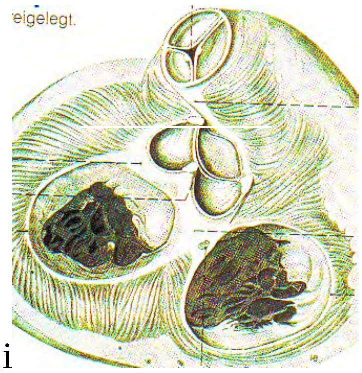


Fig. XVIII. The four valves

The annuli of the mitral and the tricuspid valve lie almost in the same plane, tilted by 45° to the sagittal plane and at the same time facing in a left anterolateral and inferior direction, in other words, facing the apex of the heart. The aortic valve, on the other hand, lies in an anterosuperior position and to the right of the mitral valve and faces to the upper right, in a somewhat anterior direction.

The three valves mentioned above are closely connected among each other by the collagenous network of the skeleton of the heart. The pulmonary valve, however, is somewhat removed from the other three valves and lies anterior and superior, as in a 90° angle, to the aortic valve and is connected to the latter through the infundibulum.



i

Fig. XIX. The four valves and the infundibulum

The tricuspid and the mitral valves assume an almost vertical position and are tilted to the sagittal plane by 45° and somewhat vertically, so that, seen from the front, they face in an anterolateral direction and downwards to the left.

The mitral valve assumes a posterosuperior position in relation to the tricuspid valve and lies posteroinferior and somewhat to the left of the aortic valve.

Fig. XX. Position of the three valves;
the aortic valve (on the top), mitral valve (left) and tricuspid valve.

Both atrioventricular valves consist of a fibrous annulus, in which the vela (cuspes) originate. The vela are joined with their loose ends to tendinous cords and with their tips to the conical papillary muscles, which can actively move the vela.

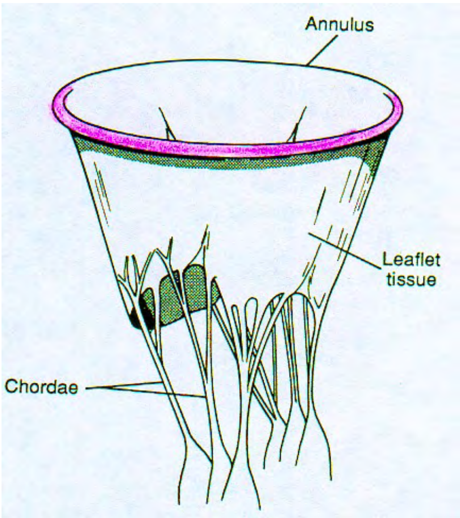


Fig. XXI. Funnel-shaped configuration of an atrioventricular valve

Each velum consists of an endocardial reflexion, containing the collagenous fibrous layer. This fibrous layer is connected to the fascicles of the tendinous cords and basally with the connective tissue of the annulus (refer to Kunzelman K.; 1993).

Each velum can be separated into three sections. Starting from the brim, the first section is rough, thick and, especially on its ventricular side, rendered uneven by the attachments of most of the tendinous cords. The atrial side of this section establishes the contact during the closing of the valve. It is clear, soft and translucent, sports a tender fibrous layer and a thicker, basal zone that reaches 2-3 mm into the periphery, has more connective tissue, is vascularized and most often contains extensions of atrial myocardium.

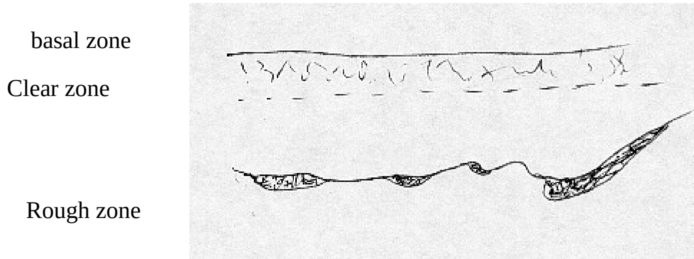


Fig. XXII. Three zones of the cusps

The fibrous annulus of the tricuspid valve, a ring made of collagenous connective tissue on the atrioventricular level consists of a bent strand that crosses the membranous part of the interventricular septum, of the tricuspid part of the right fibrous trigone, of the anterior and posterior coronary fila (long, thick strands originating in the fibrous trigone) and a more pliable layer of fibroelastic connective tissue that is embedded between the fila.

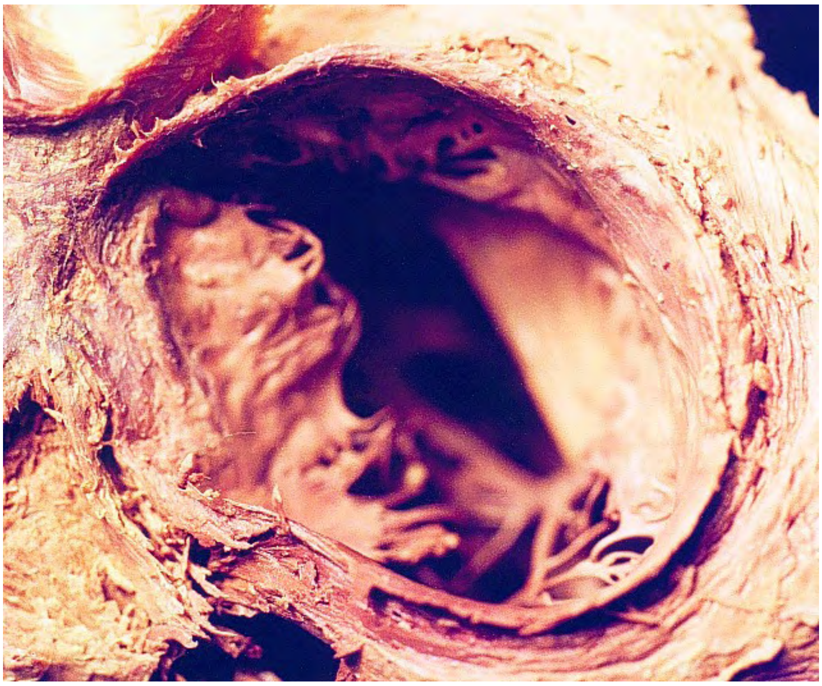


Fig. XXIII. Tricuspid valve a; annulus and vela;

The annulus is the most caudal region of the atrial wall. Its fibrous layer provides the anatomical basis of its movements (refer to Racker D., et al.; 1991).

Fig. XXIV Tricuspid valve b; vela departing from the annulus;

The three vela are also called cusps, named after the frame area of the atrioventricular opening, which is divided into anterior, posterior and septal cusp and reaches from the posterior area of the supraventricular crest to the membranous part of the interventricular septum). The anterior cusp is the biggest and the septal cusp the smallest of the vela.

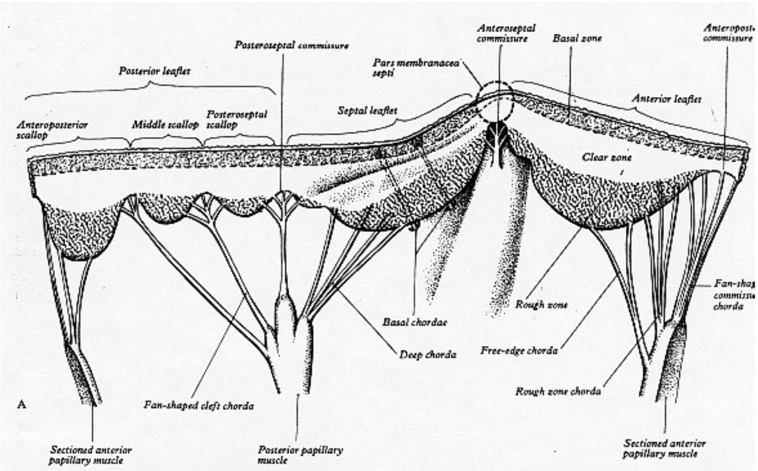


Fig. XXV. Tricuspid valve, laid flat after division of the fibrous annuli

The vela can be regarded as a curtain hanging down from the annulus. Three incisures, recesses that reach all the way to the basal attachment zone and are called comissures (anteroseptal, posteroseptal, anteroposterior), divide this curtain into three main vela. The posterior of these vela is divided once more by thin cords into three arches.

Neither is the mitral ring a simple circumferent fibrous ring, but it contains elements that interact with the fibrous layer of the vela. The consistency of these elements varies widely, which is a precondition for their functioning during a heart cycle: Changes of form and dimension are often crucial for an optimum efficiency.

Fig. XXVI. Mitral valve a

The fibrous annulus consists of parts of the right and left fibrous trigone, of anterior and posterior coronary fila extending from the trigone, and of a fibroelastic connective tissue lying in between. It is s-shaped, almost like a saddle, and it could be described as lying on two planes. The mean distance between the highest and lowest point is about 7.1 mm (refer to Kopuz C., et al.; 1995 and Flachskampf F., et al.; 1995)

Fig. XXVII. Mitral valve b; annulus;

The fibrous layer of the anterior mitral cusp spans the distance between the two trigones. It interacts with the fibrous subaortic curtain (intervalvular septum), which descends from the right posterior (non-coronary) and the left posterior (left coronary) flap valve of the aortic valve.

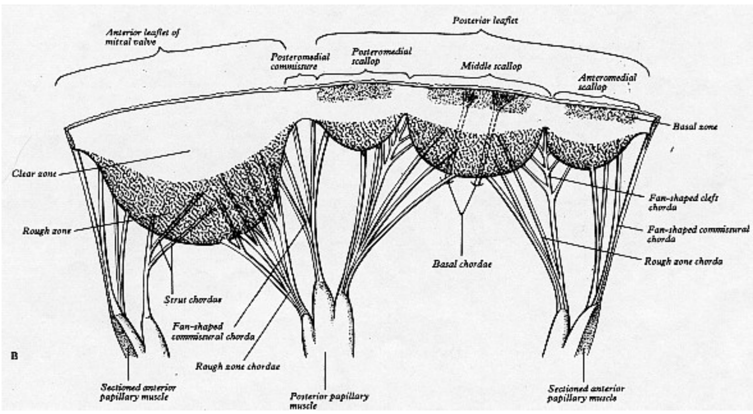


Fig. XXVIII. Mitral valve, laid flat after division of the fibrous annuli

The mitral valve is divided into a front and a back velum.

The anterior cusp (also: aortic, septal, bigger, anteromedial cusp) is big, semilunar, and shows hardly any indentations. Its fibrous layer is an extension of the subaortic curtain and, with its borders, also connected to the mitral aspects of the right and left trigone and to the roots of the coronary fila. It consists of a rough zone, on which a large number of tendinous cords attach, and of a clear, translucent zone, which, devoid of any cord attachments, contains only extensions from the rough zone in its fibrous layer. The anterior cusp doesn't have a basal zone.

The posterior cusp (also: the ventricular, mural, smaller, posterolateral cusp) is held by attachments of tendinous cords in the position of three arches (middle, anterolateral, posteromedial arch), whose rough zones act as contact areas during the closing of the valves. Once again, the clear, translucent zone is streaked with cords, and the basal zone is thick and vascularized and offers an attachment opportunity for the basal cords.

The situation of the two flap valves is very similar.

The individual valves also consist of endocardial reflexions and, in between, a fibrous layer. This layer of collagenous fibers is very distinct in the attachment zone where the layer touches the annulus as well as on the free border, in the center of which it forms the nodule.

The aortic valve, facing in a superior, right and slightly forward direction, lies anterosuperior and somewhat to the right of the mitral valve.

Fig. XXIX. Aortic valve

The fibrous aortic annulus consists of three semilunar thickenings of collagen that form three arches and surround the vestibulo-aortic connection like a three-pronged coronet.

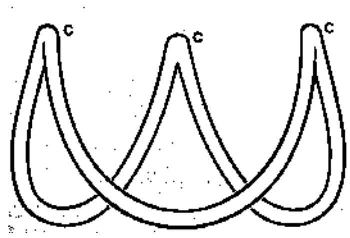


Fig. XXX. Three-pronged coronet shape of the annulus

The three flaps of the aortic valve (right coronary, left coronary, non-coronary flap) are connected to the subaortic curtain and parts of the membranous part of the interventricular septum through their central fibrous layers.

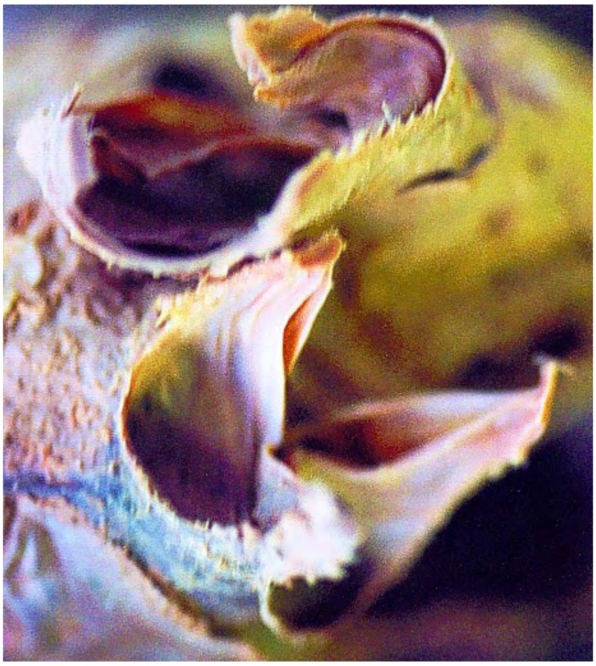


Fig. XXXI. Aortic valve; pulmonary valve behind;

The ostia of the coronary arteries open near the supravalvular crests, but mostly over them, into the sinus valsalvae which are more prominent than the pulmonary valve (refer to Navaratnam; 1993)

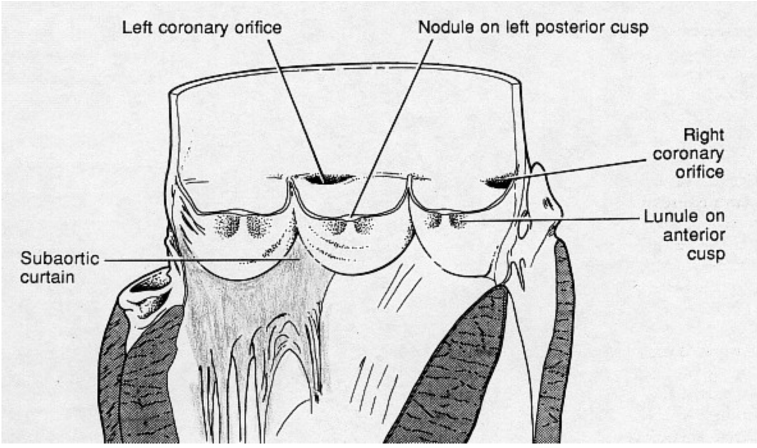


Fig. XXXII. aortic valve and subaortic curtain

The pulmonary valve is somewhat higher than the infundibulum and lies, separated from the other three valves, anterior and superior of the latter and faces to the left, up and somewhat backwards.

It also consists of three semilunar valves. These valves are attached with their convex border to the fibrous thickening of the pulmonary trunk's wall. This place is called annulus: it is the place where the pulmonary trunk passes into the ventricle and consists of three semilunar arches that, together, form a three-pronged coronet. Above the arches, the wall of the vessel is dilated, which triggers the forming of sinuses (sinus valsalvae).

Fig. XXXIII. The fibrous skeleton of the heart; right fibrous trigone

The crux of the heart is an area on the posterobasal plane, where the coronary sulcus meets the interventricular sulcus. On the inside, it consists of the connection where the atrial septum passes into the ventricular septum. These two septa are about 45° transverse to each other. They lie to the left of the middle line, and their posterior planes are oriented roughly from the right scapula to the left nipple.

The right fibrous trigone is the center of the heart and thus the center of the centrally positioned fibrous body. It connects mitral, tricuspid and aortic valves. The conus ligament reaches from the right side of the aortic base to the pulmonary base.

Fig. XXXIV. The right fibrous trigone

It is sensible to describe the fibrous skeleton not as the sum of its components, but as a continuum. It is a three-dimensional plexus of collagenous fascicles acting as the shaping form of spatial structures.

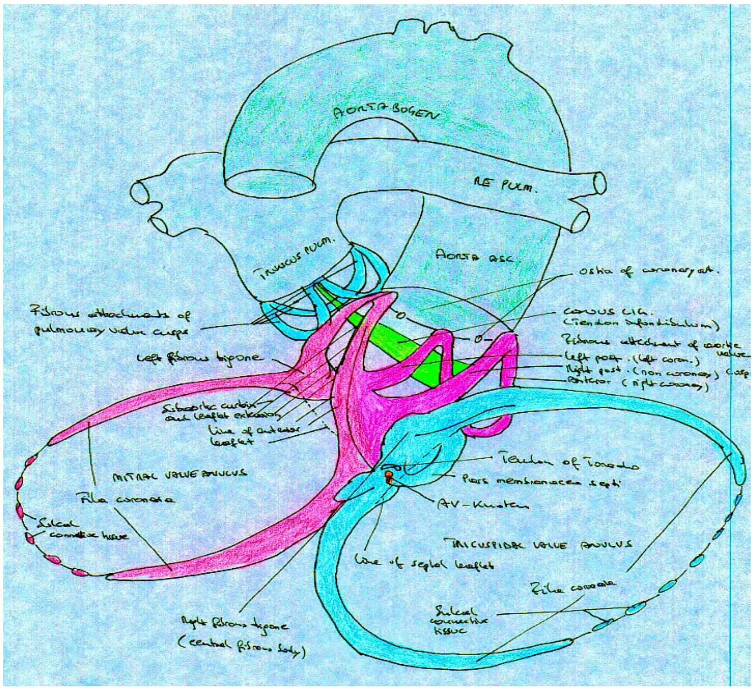


Fig. XXXV. The continuum of the fibrous skeleton of the heart

(viewed from the right, above and posterior)

There is a multitude of anatomical counterparts to the fibrous skeleton of the heart, which all concern three areas: the AV-level, the connections to the septum and atrial connections (refer to Miguel A. jr.; 1988). For transparency, I would like to list the exact anatomical elements once again:

- Trigonum fibrosum dextrum
- Trigonum fibrosum sinistrum
- Annulus valvula mitralis
- Annulus valvula tricupisdalis
- Annulus valvula pulmonalis
- Annulus valvula aortae
- Lamina fibrosa (5 cusps, 6 flaps)
- Subaortic curtain
- Pars membranacea septi ventriculi
- Lower part of the Septum interatriale
- Tendon of Todaro

6.4. Malformations, caused by abortive development of the fibrous skeleton of the heart

This section will help illustrate the great dimensions of the small center within the heart.

Disturbances of the embryonic development of the fibrous skeleton of the heart (refer to "the development of the fibrous skeleton of the heart") may be caused by one of its components which, prior to its formation, are manifold, or by a change of its position: a shift of the atrioventricular endocardiac cushions towards the ventricles during the valves' formation.

These disturbances are part of the reason for the occurence of innate cardiac diseases (refer to van Gils F.; 1981).

The fibrous skeleton of the heart is involved also with its membranous part in all malformations of the AV-canal (agenesis of the atrioventricular valves, one solitary AV-valve) as well as in the interruption of the normal rotation (refer to Bostrom M., Hutchins G.; 1988), malformations of one of the four cardiac valves (mitral stenosis, tricuspid insufficiency), in the tetralogy of Fallot, the Ebstein's anomaly which tilts the tricuspid plane by 45° (refer to Silverman N., et al.; 1995), in double-outlet ventricle (refer to Howell C., et al.; 1991) and in ventricular septal deficiencies in the membranous part.

Two important diseases will be described in the following section. In order to avoid straying from the topic, I will only discuss the effects on the fibrous skeleton of the heart and leave out the general description of the syndromes.

5% of all persons with a congenital heart disease are affected by an atrioventricular septal defect. 40% of them suffer Down Syndrome, but the disease also occurs in combination with asplenia and polysplenia, with DiGeorge syndrome, with Ellis van Creveld Syndrome and by itself.
This multitude of defects is due to malformations of the endocardiac cushions and of the atrioventricular septum.
Usually, the anterior cusp of the mitral valve is deformed and in the atrium, the septum primum is deficient.
In the partial form of this disease, there is a cleft in the anterior cusp of the mitral valve due to an incomplete fusion of superior and inferior endocardiac cushion, and a deficiency of the ostium primum (refer to Emmanouilides G., et al.; 1998).
The complete form is caused by a partition of the anterior cusp of the mitral valve due to the lack of fusion, and a great interatrial and interventricular deficiency of the septum (ASDs and VSDs), usually with only one common AV-valve that connects the atria with the ventricles.
The tendon of Todaro is developed to various extents during atrioventricular septum deficiencies, but it always forms an additional triangle (in addition to the triangle of Koch) that doesn't connect with the axis of the AV-conduction system (refer to Seo J., et al; 1992).

The tetralogy of Fallot, which originally described the tetralogy VSD, pulmonary stenosis, overriding aorta and right-ventricular hypertrophy, is also used these days to describe forms of this disease that include either pulmonary atresia or agenesis of the pulmonary valves. 10% of all malformations of the heart are Fallot's syndromes.
This disease includes membranous (perimembranous) septum deficiency, which is the result of the missing connection of the muscular with the infundibular septum, a tapered infundibulum and an abnormous pulmonary valve, the latter in most of the cases bicuspid or unicuspid with or without stenosis of the annulus.
The etiology is unknown for the most part, but it is assumed that the Fallot's tetrad as well as the transposition of the major arteries result from the stopping of the rotation of the

outflow tract and of the major vessels. These malformations therefore correspond to the carnegie-stages 15 or 18 of the developing heart, while normally developed hearts correspond to the Carnegie stage 19 (refer to Lomonico M., et al.; 1988).
The Fallot's tetrad is furthermore accompanied by an insufficiency of the cusps of tricuspid, aortic and mitral valves (refer to Howell C.; et al.; 1990).

Apart from the innate, there are also acquired valvular diseases, one of which I would like to discuss.

Valvular diseases that are acquired after the completion of the heart's development, such as the mitral valve prolapse syndrome, may be caused by a number of things. In the western hemisphere, they are rarely a consequence of rheumatic fever or syphilis. However, our longer life span, physical inactivity and high blood pressure may also cause mitral valve prolapse syndrome and stenosis of the aortic valves. Idiopathic degenerations of the two valves mentioned above still lack an explanation (refer to Rose A.; 1996).
A mitral valve prolapse syndrome consists in part of the cusp, an entire cusp or even both cusps projecting beyond the atrioventricular level during the ventricular systole.
Mitral valve prolapse syndrome often correlates with prolapse of the tricuspid valves, the latter, however, without any clinical symptoms (refer to Froom P.; et al.; 1989).
Mitral valve prolapse syndrome is more frequent in women than in men. It is easy to diagnose by means of an echocardiography. Real anatomical anomalies (floppy mitral valve), however, are difficult to find, so that the mitral valve prolapse syndrome seems to be the result of a malfunction (refer to Wann L., et al.; 1983).
Other authors propose a hereditary factor (refer to Emmanouilides G., et al.; 1998).
There are signs that patients suffering a mitral valve prolapse syndrome are frequently afflicted with scoliosis, asthenic habitus, SBS (straight back syndrome), funnel chest and hypomastia.

6.5. Tasks / responsibilities of the fibrous skeleton of the heart

The fibrous skeleton of the heart consists of various forms of cells, some of which undergo a partial change while following complex movement patterns. It's position is not by accident in the very center of the heart, on the contrary: it needs this position to fulfill its task and ensure the required functionality.

Its essential functions are:

1. The fibrous skeleton of the heart ensures the electrophysiologic discontinuity between the muscles of the atria and the chambers.
At the same time, it provides the basis for an uninterrupted communication of the specialized conduction system that consists of myocardiac cells with the ability of creating and conducting stimuli.

2. The fibrous skeleton of the heart constitutes an attachment zone for the muscles of the chambers as well as for the myocardium of the atria, even though the latter causes much less mechanic use than the first. The muscles are anchored mechanically.

3. The fibrous skeleton of the heart holds the heart in its position. It is responsible for holding a relatively stable position within the fibrous pericardium (relatively, since it moves with the heart during systole and diastole).

4. The fibrous skeleton of the heart is a stable, even though mechanically pliable, basis of the fibrous layer (the collagenous layer within the endocardiac reflexion of the cusps). Here we find a continuity of collagenous connective tissue.

Fig. XXXVI. The fibrous skeleton of the heart; aortic and mitral valve

6.6. The fibrous skeleton of the heart,
basis for an expanded osteopathic concept

A. Still asked in the beginning of the last century whether wisdom was a feature of the heart, and he answered his own question in the following way:

The heart, not the brain, is the center and the source of an intelligence shaping every region of the body and uniting all the components in one person, in one being …it is not enough to regard the heart as a pump …it possesses innate wisdom, wisdom that shows in its activity …the osteopath must follow the blood stream and eliminate all obstructions, open all doors … (refer to Still A.; 1904).

The osteopath following the blood stream: An image whose visualization leads us directly to the entwining streams leading into the heart, acting within and leaving the heart again. These streams are manifest in the fibrous skeleton of the heart (refer to "the development of the fibrous skeleton of the heart").

The fibrous skeleton of the heart is therefore the material expression of the streaming liquid.

If we grasp this concept, we can open up the fibrous skeleton of the heart to osteopathy and realize an approach to the heart that enables us to understand it in its uniqueness and allows us to touch it.

In the following section, I will once more highlight the points that are accessible to the touch of our hands. Of course, they couldn't have escaped the feeling of osteopathically schooled hands, anyway, but it is important to mention them once more, since it is this kind of reflection that turns the fibrous skeleton of the heart into a living structure and thus lets us grasp its evolution and function.

In the beginning is the stream. The stream (as in the human body, not water, but blood, i.e., liquid with solid particles, cells) has two characteristic abilities: flowing in helical movements, and pulsing (refer to Schwenk, T.; 1995).

Thus, in the beginning, there is a pulsing, flowing stream. Then, and only then, condensation can take place. Cell groups line up along the streams and build banks. If streams approach each other and stream around each other, partitions form. The partitions of liquids that are rich in solid particles are planes formed from cell aggregations. Cell groups develop to tissues, which, in their parting function, consolidate a liquid situation. A materialization becomes manifest as partitioning walls of the heart (refer to "the development of the fibrous skeleton of the heart").

From a development point of view, the dividing cell groups of the endocardiac cushions must therefore be seen as an expression of pulsing streams of liquid. The fibrous skeleton of the heart (i.e., valve attachment rings, cusps and septa), which originates from them, is an expression of the complex task of the two circulations, both of which conduct two kinds of blood, arterial and veinous. Thus, the fibrous skeleton of the heart should not be understood as a rigid and inflexible frame, but it is necessary to comprehend the movement going on within, the movement that caused its very existence and development, a movement that does not stop as long as we live.

If we touch the fibrous skeleton of the heart as osteopaths, we always touch the movement that builds its basis, too.

The fibrous skeleton of the heart lies at the innermost point of the body, hidden under pericardium, epicardium and myocardium. Protected. And still, it is the functional expression of the organ "heart".

We can see it as a conducting structure, since it is this very tissue which provides the basics for the heart's development and, later, envelops it to ensure the integrity of the electric system. In the housing of the fibrous skeleton of the heart, the conduction system can work undisturbedly.

The fibrous skeleton of the heart also holds together the elements that are not supposed to come loose, i.e., the myocardium.
Thus, it is the safeguard of the unspecific and specific cardiac muscle fibers' function. The major part of the heart's mass is muscle tissue. Without the fibrous skeleton of the heart, this muscle tissue would remain in a dysfunctional state.
In order to approach this inner structure, this fibrous skeleton of the heart, it is necessary to establish the relation between the myocardium and its contraction on the one hand and the valve level on the other. The contractions and relaxations of the muscle fibers are not a totally independent movement, but the acting forces also act on the tissue of the fibrous skeleton of the heart.
As always, the hands of the osteopath must establish a contact to a structure that lies deep within the human body, in the process overcoming and discarding information of other structures that lie closer to the body's surface in order to feel a much more tender movement beneath (whenever we want to feel the movements of the ventricular system under dura and cranial bones and even the brain, or when we want to feel the motility of the liver and have to palpate through ribs, muscle and capsule of the liver).

The fibrous skeleton of the heart, this innermost structure, is in its position right in the heart not only sheathed by the myocardium, but also, as the myocardium, engulfed by pericardium. The coating of the pericardium does not only envelop the muscle, but it is also attached to the diaphragm on the one hand and to sternum and spine on the other and even, by means of its reflexions, on the major vessels (refer to "anatomical and physiological facts").
These vessels are in turn nothing other than a continuation of the blood stream after the latter has exited the cardiac valves. They are therefore also a reflection of these streams' movements, which are also manifest in the fibrous skeleton of the heart, which, after all, forms the valves.
The heart is sheathed and held by the pericardium and, at the same time, suspended within the pericardiac sac and thereby fixed in its position. The reflexions of the pericardium to

the epicardium run, after all, partially along the (up to three) centimeters of the vessels that lie within the paricardiac sac. Thus, they reach into the close vicinity of the fibrous skeleton of the heart.
I don't want to belittle the significance of the pericardium and its attachments by any means, but it is necessary to understand this connection: because, to look solely at the outer wrapping while the interior lies so close seems not justified when faced with the heart as an entity.

At this point, I also want to mention the special position of the heart.
The heart assumes a very protected position within the bones of the chest. It is enclosed by spine, sternum, ribs and muscles, and additionally cushioned by the lungs. Within this protective frame, it still has enough room to pulse and move. It is logical that this constantly moving and life-securing organ should be placed in a position that is protected against outside influences and still leaves enough room for the organ's movement.
However, the aforementioned reasons are not the only advantages of the position of the heart: The position so close to the lungs assures a maximum efficiency in the two organs' interaction, which I will describe in detail in one of the following chapters (refer to "further considerable facts").
The heart as an organ expresses itself in movements. Therefore, it must be comprehended fully, not only in its innermost core: a pulsing organ existing in a protected realm.
The movement of the heart extends along the long axis of the left ventricle for about 12.8 mm, give or take 3.8mm. The apex is the place of minimum movement (refer to Rogers W., et al.; 1991).
This movement consists in a counterclockwise contortion. One could say that the contortion is the characteristic movement of the left ventricular contraction (refer to Hansen D., et al.; 1988).
Still, the muscular movements shouldn't be considered without considering the valves at the same time.

If the mitral valve is removed, for instance, the movement along the main axis during systolic contraction is markedly shorter (refer to Gams E., et al.; 1992).
In general, it should be noted that the movements of the valve plane mechanism (VPM) are not only a result of the heart's contractions: They are also caused by the blood flow within the heart and the major vessels, as well as by the acting muscular forces and the elasticity of the suspension mechanism. The effect of the valve plane mechanism shows in its influence on the economical action of the heart (refer to Krasny R., et al.; 1991), even though the amplitude of the VPM's movements, as a result of its limited function, is markedly shortened during coronary heart diseases and myocardiac infarcts. (refer to Höglund, et al.; 1989).

Finally, it ought to be mentioned that the heart does not only develop as an unpaired organ in a non-median position, but is also the first asymmetrical organ of the developing life.
In other words, the development of the heart is the first manifestation of the asymmetry of the human body.
This fact may be the point of departure for many other reflections. It seems important in this context that at the same time the asymmetry develops, the life-preserving measure of blood supply to the whole organism is also implemented.
From a geometric-physical point of view, asymmetry leads to a shift of the equilibrium and an emphasizing of one side. It is yet unknown if there are any effects on the axes that develop, but it seems probable that an asymmetrical input in a hitherto symmetrical system has some kind of effect.

Maybe, the heart and its inner structure, the fibrous skeleton of the heart, are now easier to grasp. It might have seemed inaccessible up to now, due to the complexity of its functions.
Within the human heart, form and movement interact and interweave space and time in a rhythmic action: this organ is not only a physical entity, but also a movement in the stream of time (refer to Schwenk T.; 1995).

It is not enough to view the heart as a muscular pump; it is also an intelligent structure, not a working machine, but the expression of a system we call circulation (refer to Harvey W.; 1628) and which is nothing other than the guarantee of our life. This system supplies nutrition, discards waste and secures the survival of all other structures within the body. The osteopath, with the hands placed on the body of the patient, grasps in the mind all fluxes within this body.

Fig. XXXVII. The fibrous skeleton of the heart;
fibrous trigone and annulus

7. Further facts worthy of consideration

7.1. The unity of heart and lungs

A. Still was one of the first to suggest treating heart and lungs as a single entity.

These two organs are situated within and protected by the bones of the chest, a position from where they assure our vital functions.
Their interaction becomes manifest in their similar position, both organs being held and enveloped by an upper and lower diphragm, and markedly separated from the neck and abdominal regions.
The structures passing from the throat to the abdominal region, such as the esophagus, pass them by in mere observation, and other structurs, even though situated in the thoracal region, such as the thymus gland, seem to be outsiders in this game.

Lungs and heart cooperatively ensure the supply of oxygen to the blood and the elimination of carbon dioxide, thus providing the vital basis of our soma.
It is logical that the two organs are designed to realize this cooperation as efficient as possible. Efficiency, as far as the body is concerned, means keeping the energy consumption low while achieving a maximum of performance, or rather a performance fitting the respective situation.

The question is, how can these two organs, working full time, coordinate their respective functions?

One approach could lie in the fact that the movements of the lungs during deep breathing, accompanied by a considerable drop of the diaphragm and strong movements of the ribs might provide a basis for the efficiency required.

And, indeed, this interaction exists insofar as deep breathing, especially strong inhalations, lead to a significant cardioacceleration and a change of the QRS axis (refer to Mohan M., et al.; 1986).

This phenomenon, however, is linked with an increased energy consumption and is therefore not apt to provide the required optimum efficiency.

Efficiency can be achieved if the ventilation of the lungs is not regulated by forced breathing, but rather by a change in position of the heart; this feat is all the more remarkable as such a shift in position can only be of the most minute range.

It is therefore a fact that changes of the regional air volume of the lungs are not caused by altered positions of ribs or diaphragm, but that it is the intrathoracic position of the heart that governs the regionally differing alveolar expansions.

In this manner, the total volume of the heart can be kept at a constant level (not possible any more during, e.g., atrial fibrillation), and the heart minimizes the energy consumption by avoiding any excessive demands as may be caused by movements of the lungs (refer to Hoffman E., Ritman E.; 1987).

The next relevant question is, how is this feat realized?

As I mentioned earlier, I executed dissections of whole-body preparations before writing this study, in which I paid close attention to the position of the heart and its axis and the relation to other axes of the body, especially the pulmonary axes.

The heart itself can be described by two axes. On the one hand, the axis of the atrioventricular level, on the other hand the axis of the septa.

Spatially, these axes cross each other in much the same manner as the parameters of the lungs. In the lungs, the fissures (right and left oblique fissure of the lungs) show a very similar orientation, coming from a transverse upper dorsal direction and running downwards towards the front.

If you limit yourself to indicating the axes of the heart and the fissures of the lungs with precise parameters, which, in fact, would be possible (e.g.: the fissure goes from the 4^{th} to the 6^{th} rib), you miss out on the possibility of experiencing the interaction of the two organs' movements.

In other words, the spatial orientation of the organs heart and lungs is similar in the following way: The axis of the atrioventricular level points in the same direction as the oblique left fissure of the lungs, the latter being in continuation of an imaginary line through the first. The right oblique fissure, on the other hand, is in continuation of the axis of the ventricular septum.

Since words are often an inadequate means of depicting spatial circumstances, I would like to introduce the following pictures as an illustration of the relation between the axes of the heart and the fissures of the lungs.

Fig. XXXVIII. Heart in position, pericardium removed, both atria removed; Aorta and A. pulmonalis prepared; The inferior lobes of both lungs in situ, the other lobes held artificially up to make the fissures visable

Fig. XXXIX. Atrioventricular axis running in the left oblique fissure (shown via peace of metall)

Fig. XL. Long axis of the heart running in the right oblique fissure (shown via peace of metall)

If we keep thinking in three-dimensional terms, we might want to compare the movements of the heart along and within its axes and their continuations, the fissures of the lungs, to the movement of waves that roll on and peter out unbroken on the other side of a lake.

Maybe this can serve as an approach to explaining the communication between the one organ with its pliable plasticity and the other with its rhythmic movements, and the quality of their coordination.

7.2. Further important bases for osteopathic techniques applied on the heart

In this section, I want to discuss three topics that are of utmost relevance for all osteopathic techniques that are applied on the heart.
These three sections will round off the picture of the heart in its framing entity, the body, considered before as well as right after the birth and in relation to the spatial orientation and posture.

7.2.1. Embryonic relations

In the osteopathic approach of a patient, it is not only necessary to understand the patient in his/her chronology, but also to establish the latter's relation to the embryonic development.

It is impossible to cover the development of human life in a single paper, especially if it is not the main topic.
Still, I would like to mention a few relations concerning position and chronology of the heart to other organs and illustrate them with some graphic figures.

In the beginning of the 4^{th} week, at a crown-rump length (C.R. length) of about 4 mm, the cardiac looping takes place. At the same time, the otic vesicle closes up, the neural tube shows three vesicles, the hypophysial placode starts to differentiate, the pharyngeal arches close around the stomadeum and the mesonephron starts to form (refer to Wolff-Quenot M., Sick H.; 1997).

In a transversal section, the heart is perceived as an S-shaped body, the arterial bulb to the right, and the primitive atrium connected to a primitive ventricle by the AV-canal.

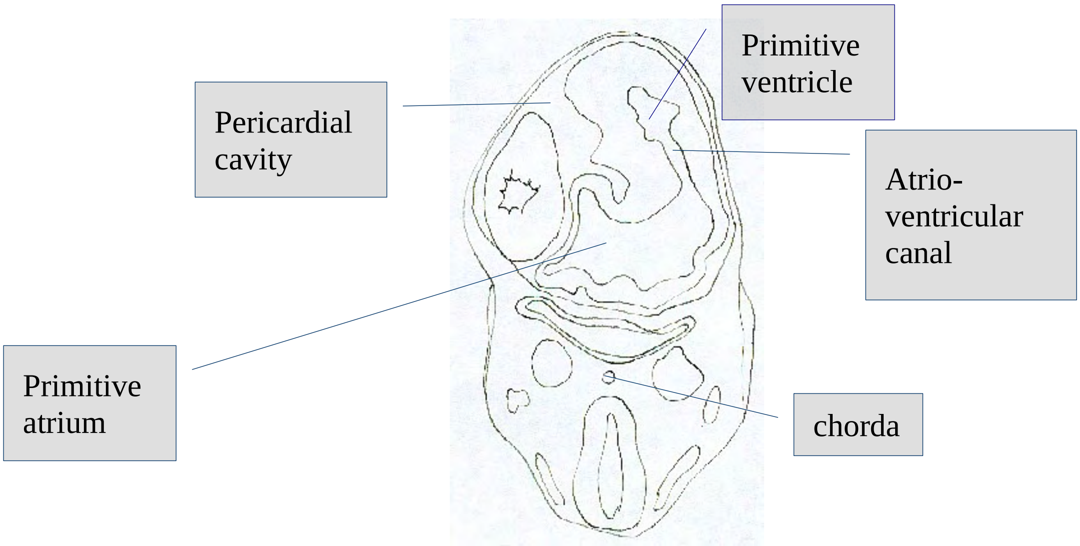


Fig. XLI. 4 th. week during embryonic development, transversal section

During the 5th week (refer to C.R. length: about 8 mm), cardiac septation starts. At the same time, the cephal neural tube develops a bend, the two opposed pancreatic buds and the nasal prominence form and the wolffian duct drains the mesonephron.

In a transverse section, the beginning of the heart's septation can be perceived, as well as the trachea, which is isolated from the esophagus.

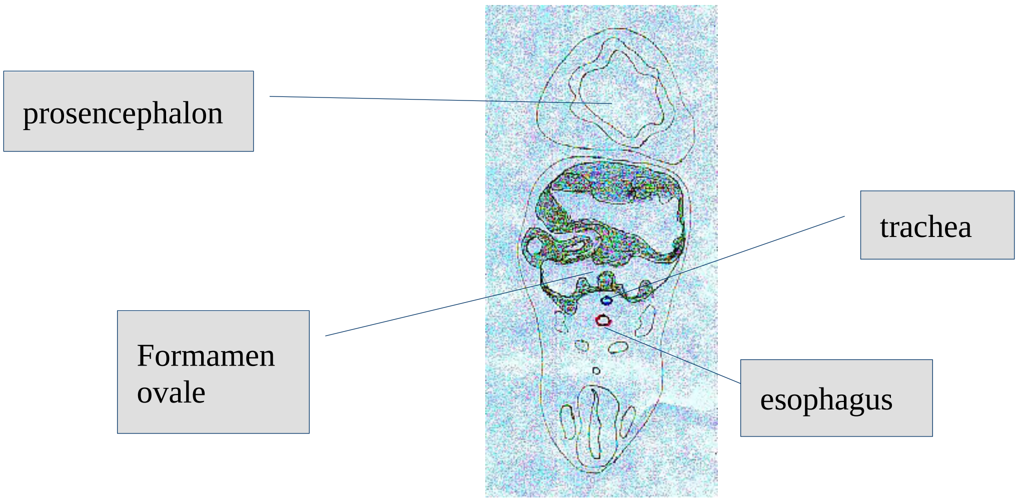


Fig. XLII. 5 th. week, transversal section

During the 6th week, the septation continues and the arterial bulb separates. At a C.R. length of about 13 mm, the evagination of the encephalic hemispheres takes place, the cochlea and the endolymphatic duct differentiate, the Rathke's pouch closes up and the infundibulum forms.

A sagittal section shows the closeness of the tongue to the heart and the transverse septum between heart and liver.

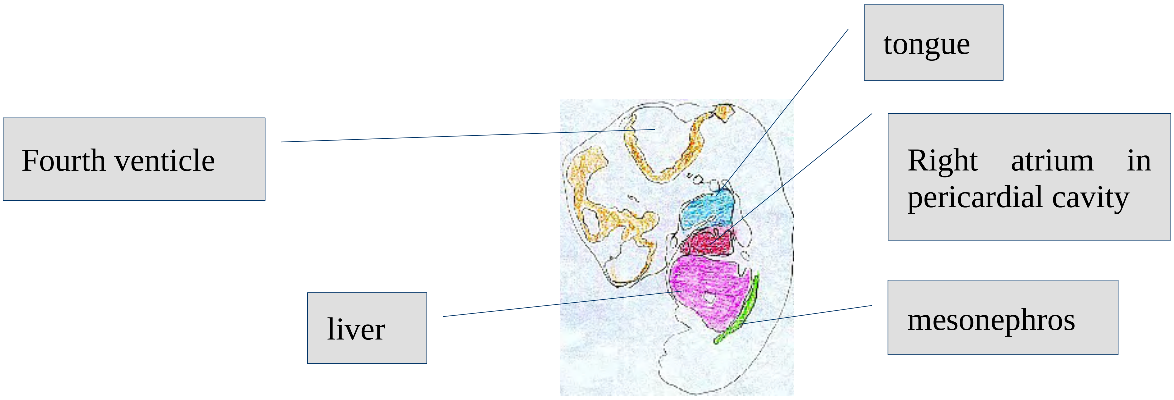


Fig. XLIII. 6 th. week; sagittal section

The transverse section shows the impressive septation of the heart.

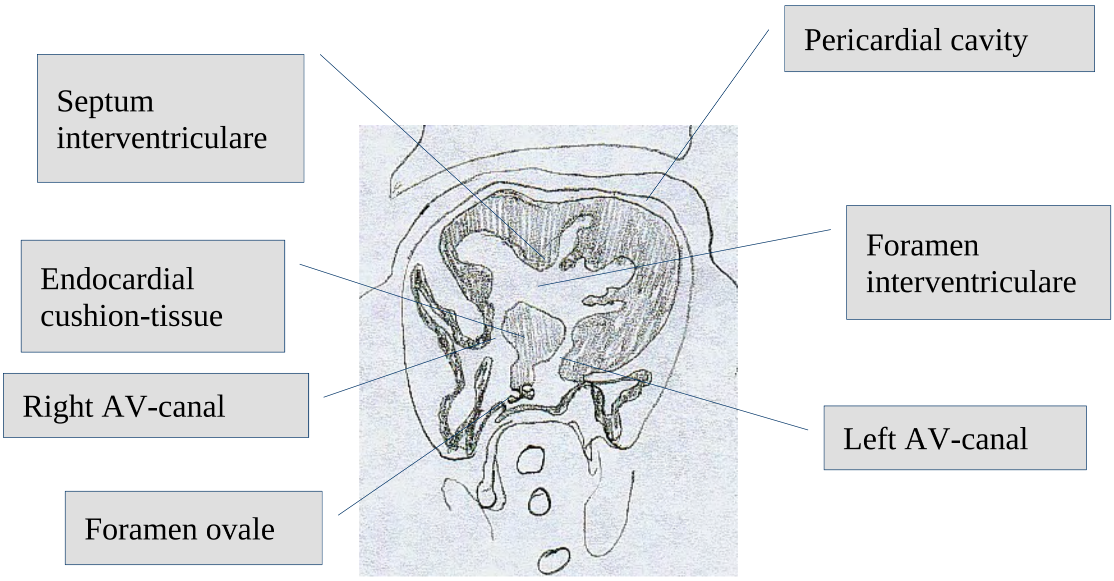


Fig. XLIV. 6 th. week, transverse section

In the course of the 7th week, at a C.R. lengt of 28 mm, the septation progresses visibly towards completion. Simultaneously with the closing up of the interventricular foramen, the pleural cavity separates from the pericardial cavity around the phrenic nerve, the cochlea starts to roll up, the interventricular foramen of the developing brain form and the maxillary prominences unite with the nasal prominences.

A transverse section shows clearly the three physical cavities that developed from the intraembryonic celum. Peritoneal, pericardial and pleural cavity.

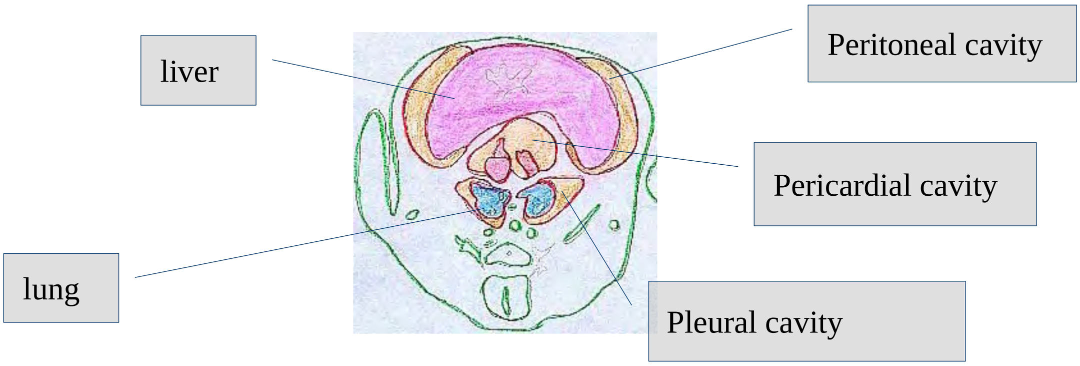


Fig. XLV. 7 th. week; transverse section

7.2.2. Conversion of the circulation

For the treatment of new-borns and children, it is essential to be familiar with the changes that the heart and the circulation undergo during and after birth.
The understanding of these changes is not only necessary for the detection of pathologies that might occur at this level: Even for perfectly healthy children, this change is a major event effecting massive physical changes.

The first cardiac actions can be witnessed starting with the 21st day.
The pulse rate during the fifth week is about 100 bpm, continually rising to a high of 160 to 180 bpm in the 8th week and slowly falling again hereafter, so that the average heart rate at the time of birth is about 140 bpm with a deviation range of 20 beats up or down.

The fetal circulation differs from the postnatal circulation in the following points:
First of all, the placental circulation works parallelly, meaning blood flows from the iliac arteries to the umbilical arteries, through the placenta, the umbilical vein and the ductus venosus into the inferior cava, and secondly the pulmonary circulation hardly works at all, the blood flowing from the right atrium throught the foramen ovale into the left atrium, and the blood from the pulmonary artery flowing for the most part through the arterial duct into the aorta.

After birth, a major change occurs, caused by the shutting down of the placental circulation and the child's starting to breathe through the lungs.

The umbilical arteries and veins close up right after birth, but this closure, brought about by contractions of the vessels' muscles, causes only a functional shutting down of the placental circulation. Only during the first days and weeks, the lumina of the vessels close up with connective tissue.

The umbilical vein forms the round ligament of the liver, the ductus venosus turns into the venous ligament of the liver, and the umbilical arteries become the medial umbilical ligament and the superior vesical artery.

The first breath after birth reduces the flow resistence in the lungs, the blood flow through the pulmonary artery increases and the arterial duct (Botallo's duct) closes up, as a reflex at first, later with tissue. The increasing flow of blood flowing from the lungs into the left atrium presses the primary onto the secondary septum, dividing the right atrium from the left, hemodynamically at first, later with tissue.

The foramen ovale becomes the oval fossa with the limbus fossae ovalis, the arterial duct becomes the ligament of Botallo.

Therefore, we can say that the transition from fetal circulation to the fully developed circulation takes place as a sudden event, in a functional sense, and on the other hand, it takes days and even weeks until the by then superfluous fetal shunts and vessels are obliterated by connective tissue.

7.2.3. Posture

By now, the position of the heart within the thorax has been amply discussed, as well as the interaction of the heart and the bone structures (spine, ribs, sternum) during the embryonic development (refer to the previous chapters).
What remains is the influence of the posture on the position of the heart.

The proper tool for the determination of the heart's position is the ECG.
As soon as the electric axis of the heart has been established, the heart's position can be determined within certain limitations (refer to Stafford M., Stafford D.; 1993).
Considering the anatomical connections and the embryologic developments, it is not surprising that alterations of the protective frame, such as lying down, standing, crouching, slouching or standing upright have as much of an influence on the intrathoracic position of the heart as the movements of the diaphragm and the lungs.

Thus, a clear change of one of these parameters, such as a change in posture, leads to an alteration of the anatomical orientation of the heart within the thorax that shows in an alteration of the electric axis of the heart (refer to Mohan M., at al.; 1987).

But not only short-term changes in posture, but also slowly progressing changes such as cyphosis that increases in old age, but also an increase in body weight and obesity cause the heart's axis to shift towards the left (refer to Guazzi M., et al; 1984).
It is an interesting phenomenon in this context that the development of a deviation of the axis of the heart (QRS factor frontally 45-90°) is an indication of imminent ischemic cardiac diseases (refer to Rabkin S., et al.; 1981).

(For more information concerning the electric axis of the heart refer to the appendix)

7.3. The thoraco-abdominal balance

As I described above, the thoracic region may be seen as a functional entity.
Still, this region is closely connected to the abdominal region, not only by the diaphragm, which functions as a separating border for both cavities.

At this point, for the sake of completeness, I would like to give a short description of the interaction between the two cavities. This interaction is described mainly by the action of the diaphragm and could be called thoraco-abdominal balance. For a more detailed study of this balance, please refer to a physiology textbook.

The diaphragm is the most important respiratory muscle. It's action leads to changes in pressure. During normal respiration, the diaphragm has an amplitude of about 1 cm, if the respiration is forced, the amplitude can increase to up to 10 cm.

During contraction, the diaphragm flattens, pushes downwards and spreads out.
This leads to an increase of the vertical diameter of the thoracic cavity and simultaneously increases the abdominal pressure, pushing the organs of the abdominal cavity down and out, thereby also increasing the transverse diameter of the thoracic cavity.

Since the diaphragm is covered by the parietal pleura, it causes the pleura to follow its movement down and out during contraction.
This leads to a drop in pleural pressure (i.e., the pressure in the pleural cavity around the lungs), leading to a drop in the alveolar pressure.

Since the alveolar pressure sinks below the atmospheric pressure, the air follows the pressure gradient and streams into the lungs until the alveolar pressure has reached the level of the atmospheric pressure, eliminating the pressure gradient.

During exhalation, the diaphragm relaxes.
The pleural pressure rises and causes a rise in alveolar pressure, creating once more a pressure gradient, this time leading towards the mouth.

Air flows out. The volumina of lungs and thorax decrease, and pleural cavity as well as alveoli reach a pressure level similar to the one prior to inhalation, i.e., pleural pressure -5 mmHg and zero alveolar pressure.

During this ideal diaphragm action, the abdominal pressure is always positive, but never exceedingly increased, just as the negative pressure of the lungs never becomes positive, as it is the case during various pathologies as well as during forced exhalation with contraction of the abdominal muscles: in these cases, the positive pleural pressure may lead to a temporary collapse of the bronchi and a decrease in breathing volume.

Therefore, the thoraco-abdominal balance fulfills the function of a pressure gauge for the body and guarantees the optimum venous backflow to the heart.

It has been found that a decreasing growth of the abdominal circumference leads to an increase in enddiastolic and endsystolic volumes of the left ventricle (refer to Soames R., Atha J; 1982).

This influence works the other way, too: If the hemodynamic function of the thoraco-abdominal pumping system is inhibited, as it might be the case during valvular diseases, the capacity of sucking blood to the heart is greatly reduced. This insufficiency leads to the development of related pulmonary diseases as well as to increasing hemodynamic disorders (refer to Andrianov I., et al.; 1983).

7.4. Emotional components that should be considered

Whenever we touch another human being in our function as osteopaths, we also establish a contact from one human being to another.

We never touch somatic structures as such, even though they may be our main interest, but always our patient as an entity, with all his thoughts, emotions, experiences from the past and plans for the future encased in the form of this body he or she allows us to touch.

In our work with the heart, we have to be even more careful of emotions, since we are touching a strucure that is not only very protected, but also vested with everything we call our innermost essence.

The heart has always been and still is the subject of myths, fairy tales, legends and spiritual practices, which are characterized by the culture that produced them. The common denominator of all these narrations, however, is the idea of the heart as a center (the very heart of things, as we say). The heart stands for the most intimate and at the same time for the most cherished things.

Even in everyday language, many expressions including the word "heart" refer to emotions and social feelings, such as to strike somebody in the heart, to be good-hearted, to have a heart of stone, "hearty" etc.

It is easy to see that the heart is attributed a variety of emotions, feelings of love, devotion and spiritual insight as well as lust for revenge and implacability. The never-ending flood of romantic novels is an indicator for the strong desire for being touched in the heart.

One of the most frequent topics of psychotherapeutic processes is the unification or the separation of feelings of the heart and of the loins, love and sexuality, which, in one individual, may be directed at different persons.

The holding back of feelings from the heart, the incapability to commit oneself completely to another person, is described as a disturbance triggered by a traumatic experience, be it in childhood or as an adult.

Experiences such as continuous rejection, grave abuse of confidence or repeated abandonment injure the heart. Drawing back and directing one's feelings inwards is the resulting symptom.
Persons whose hearts have been injured in such a way often try to compensate for their emotional inabilities by being excessively perfectionist and performance-oriented, while their relations become more and more limited. An orderly life following strict rules and fixed courses is their anchor against further commitments to other persons and thus their protection against new injuries.

The heartbeat is a rhythm symbolizing life itself. At the same time, however, this rhythm can be an indicator of disturbances. In the same way that excitement can cause the heart to beat faster and stronger and the skipping of beats indicates disturbances, some disturbances of the heart's rhythm are nothing other than a chronified symptom of anxiety, an expression of apprehension and pressure.

It is logical that patients with an acquired valvular disease have a much lower tolerance of frustration and stress and exhibit autoagressive tendencies. Somatic symptoms lead to a feeling of continuously lurking danger and to symptoms of anxiety (refer to Nasilowska-Barud A., Markiewicz M.; 1991).

Physical work with the heart requires a basis of mutual trust, a strong relation (refer to Klußmann R.; 1992), in which it is possible to open up to the other.

Because, if nobody is there to open the door from the inside, it would have to be taken down and broken, eliciting even more resistance and evasiveness from the being the therapist intends to cure.

If doors are opened, however, and if there is commitment, and strong feelings are allowed to surface, then the patient is in need of an emotional companion, of holding, and maybe of talking.

It is important for the therapist to bear in mind that he touches the innermost component of the other, the essence, the heart of gold, and that he gets to see secrets and fears of the other.

This is not to be taken for granted, it is a present from the patient to the therapist. It comes from the heart.

This trust should be met with respect and truthfulness (cross my heart) as prerequisites for each touch and especially for touching the heart.

8. A new approach requires new osteopathic techniques

The theoretic reflection about the heart and its inner structure, the fibrous skeleton, led almost necessarily to considering practical applications.

My osteopathic tools, my hands, trained to sense the most minute movements of a vast range of physical structures, were eager to unveil the fibrous skeleton of the heart, to make it palpable. And of course, to develop therapeutic approaches in the process.

In this chapter, I will introduce some new techniques, all of which I have developed over a period of several months.

The direct feedback of many patients during that time didn't only increase the amount of information I was able to gather, but also my enthusiasm for the project.

Thus, I am able to hope that the techniques described below will be put to practice and incite other research projects.

8.1. 1st technique (atrioventricular level)

Establishing contact with the patient:

The therapist sits on the right hand side of the patient. The patient lies on his/her back.
The caudal hand of the therapist lies above the sternum, about the same level as the 4th rib, pointing somewhat up and to the left, the finger tips point to the left axilla, the base of the hand points to the 6th rib on the right (needless to say, the exact position of the hand has to be adapted to the size of the thorax, of the heart, any postoperative changes in the heart's position, etc. The positions I describe are only tools for a rough orientation).
The cranial hand of the therapist lies parallel to the caudal hand, so that if the thumbs are slightly lifted, the forefingers (in a parallel position) touch each other.

Execution:

The forefingers (their total length) lie approximately along the atrioventricular level.
As soon as the patient is breathing calmly and regularly, the therapist can start palpating into the depth (a listening process similar to, e.g., the palpation of the motility of the liver). This phase is not aiming at feeling the tensions in the bones of the thorax or in its muscles, and even the tensions of the pericardium are only to be sensed without intervening: the real important task is to grasp of the activities on the valve level.
These movements are to be mentally separated into four different kinds of movement. The first of these goes up and down, in synch with the respiration and caused by the diaphragm, the second is an up-and-down movement, also, but four times as fast and with a much lower amplitude, caused by the shifting of the AV level during systole and diastole. Third, a lateral movement corresponding to the contraction and extension of the valve attachment rings, and fourth, a movement describing a lying figure eight leaning

somewhat forwards and to the lower left. This last movement, which I would call cardiomotility, is caused on the one hand by the movements of the heart itself, systole and diastole, and on the other hand, it is probably a result of the heart's absorbing all continuously acting forces, the pull of the myocardium and the valves, and finally a reflection of the embryonic development. In the best of cases, this figure eight-movement is executed harmoniously, with two loops identical in size, no interruptions of the movement and no lateralization.

In order to harmonize this lemniscate (lying figure eight) movement, you can find the relative resting point (RRP) of the 8 with your hand, at the crossing point of the two loops, which, anatomically, is identical with the right fibrous trigone of the heart, and follow the loops of the 8 in time with its own movement. It is crucial to always go back to the RRP and start from there. Since this is a very subtle technique, designed to stimulate an existing potential without exerting any pressure, it is sensible to continue executing this exercise for several minutes.

Fig. XLVI. Atrioventricular plane; lemniscat-movement

Effects:

The central effect is a regulative re-orientation of the fibrous skeleton of the heart, which, in a fully developed heart, is part of structures serving different functions (refer to "the anatomical substratums of the fibrous skeleton").

In more detail, the effects are, for one, a harmonization of the valve attachment rings effecting not only an improved action of the valves in relation to each other, but also a possible regulation of the individual vela (flaps) of the valves, which, after all, interact via their collagenous fibrous layer with the attachment rings. (An application of this technique, e.g. in the case of mitral valve prolapse syndrome, would be of utmost interest.) Furthermore, it is possible to take influence on the cardiac conduction system. Theories based on the teaching of a basic regulation by Pischinger (refer to Pischinger A.; 1998) might explain the modification of the electric cardiac action through harmonization of the fibrous skeleton (e.g., temporary discontinuation of palpations). After all, the fibrous skeleton houses the cardiac conduction system and provides protected continuity within an anatomical discontinuity between atria and chambers.

Note:

1) Don't ever use pressure in the execution of this technique, the contact your hands make stays a light touch throughout (pressure wouldn't only compress the bone structures and strands and thereby impede the approach to the fibrous skeleton of the heart, but it would also elicit justified resistance in the patient).
2) The lemniscate movement must not be forced, the movement of the hands remains a following of the existing movement. Don't give in to any temptations of enlarging the figure eight or similar ideas (it might lead to disturbances in the rhythm of the heart).
3) Whenever a technique concerning the heart is executed, the emotional aspect must be given special attention. The therapist should bear in mind that the implementation of such techniques often triggers strong emotional reactions. He should be able to deal with emotions appropriately and to act as an emotional companion of the patient (refer to the chapter "emotional components that should be considered").

8.2. 2nd technique (atrioventricular level - interventricular septum)

Establishing contact with the patient:

The therapist sits on the right hand side of the patient. The patient lies on his/her back.
The cranial hand of the therapist lies on the atrioventricular level (refer to the 1st technique).
The caudal hand is turned about 90° in relation to the cranial hand, the middle finger of the caudal hand touching the forefinger of the cranial hand lightly at the approximate level of the interphalangeal joint. The base of the caudal hand points not quite to the apex of the heart (the forearm of the caudal hand rests as the latter's prolongation on the patient).

Execution:

As indicated above, the cranial hand now lies above the atrioventricular level. The caudal hand rests approximately along the long axis of the interventricular septum, which assumes a screw-shaped position due to the right ventricle's encircling the left.
Once more, the cranial hand of the therapist follows the figure eight movement of the fibrous skeleton of the heart around the attachment rings of the valves (refer to the 1st technique).
The caudal hand of the therapist follows the moves of the ventricular septum. This movement is for the most part a palpable shortening of the long axis during contraction and an extension during the filling. This movement does not only follow the long axis, but takes a helical twist.
After the therapist has spotted the RRP of the lemniscate movement, he may coordinate the two movements, meaning that the uppermost part of the movement of the interventricular septum should meet the relative resting point of the figure eight movement of the fibrous skeleton.

The moment when the two movements meet is perceived by the therapist as some kind of "anchorage", or, in other words, as a short-time development of the RRP into a stillpoint (refer to Jealous J.; 1999). In this moment, the therapeutic forces may be perceived: the quality that comes with this perception is similar to a light electric shock.

Fig. XLVII. Lemniscat and Pars membranacea septum ventriculi meeting in the right fibrous trigone

Effect:

From an anatomical point of view, the goal is a re-orientation of two structures pertaining to the fibrous skeleton of the heart and meeting in the right fibrous trigone of the heart: valve attachment rings and membranous part of the ventricular septum.

The therapist employs this technique in order to reflect a step of the embryologic development, the closing of the initially existing interventricular foramen in the seventh week after the conception (refer to "the embryological development of the heart" and "the development of the fibrous skeleton of the heart").
This technique also influences the conduction system of the heart, since the AV-node, which lies above the right fibrous trigone of the heart, continues through the membranous part by means of the bundle of His (refer to "anatomical and physiological facts").

Note:

1.) I recommend to apply this technique only after the application of the first technique.
2.) It is sufficient to achieve the "anchorage" only once during a single session, multiple anchoring even seems to overcharge the system.
3.) Emotional components (as mentioned above)

8.3. 3rd technique (atrioventricular level - pericardium)

Establishing contact with the patient:

The therapist sits on the right hand side of the patient. The patient lies on his/her back. While the therapist finds the atrioventricular level with his cranial hand (refer to the 1st technique), the caudal hand establishes a contact with the entire pericardium. It is necessary for the hand to assume a U-position, the lateral part of the small finger, the base of the hand and the thumb resting to the left and above the sternum and the opening of the U pointing towards the jugular notch of the sternum and its prolongation, the forearm, pointing towards the apex of the heart.

Execution:

The therapist finds the lemniscate movement of the fibrous skeleton of the heart with his cranial hand.

The caudal hand feels for the tensions of the pericardium. The point is not so much to find the tensions of the fibrous suspension (ligaments), but rather to feel the pericardium as a sac housing the heart and being attached to the major vessels with its reflexions (transition parietal pericardium to visceral pericardium, refer to "anatomical and physiological facts").

If the therapist follows the movements of both hands, he/she feels a "vibration" of the cranial hand within wave-like movements of the caudal hand, accompanied by, especially lateral, shiftings. In the course of the technique, moments of stillness are reached which ought to be held, all the while following the still changing patterns of the movements. After several still points, the shiftings decrease in amplitude until they are not palpable any more. The hands' movements feel harmonious now, similar to the swinging and swaying of a leaf on a calm lake with just the barest of waves. The therapist should follow this swinging of the waves for some time to make sure that no more shifts occur.

Effect:

This technique aims at coordinating the attachment regions or, in other words, the relative fixed points of the heart with each other.

The heart, hanging free in its pericardium, has the fibrous skeleton as its relative fixed point. The reflexions of the pericardium around the major vessels, which in turn originate with their valves in the pericardium, may be perceived as a reinforcement of the fixed zone that attaches the vessels to the pericardium and vice versa.

The application of this technique has the greatest effect on the three-dimensional, spatial positioning of the heart, its vessels and its sac. The technique makes it possible to influence the position of the heart within the heart sac in relation to the free space around the heart as well as in relation to the attached vessels, which are constantly moving links between the heart and its sac.

Note:

1.) I recommend to apply this technique only after application of the 1st, or, better still, the 1st and the 2nd technique.

2.) The "U" formed by the hand must not be too tight. If the fingers are too close together, the patient will experience a feeling of confinement, probably due to an imaginary limitation of the heart's radius of action (compression). Therefore, in the course of this technique, the patient should be asked repeatedly how he/she feels.

3.) The technique must be executed until a harmonious movement has been reached.

If the technique is interrupted prematurely, the patient is left with a feeling of disorientation or need for re-orientation, which, understandably, is perceived as very disagreeable and even frightening.

8.4. 4th technique (heart - diaphragm - liver)

Establishing contact with the patient:

The therapist sits on the right hand side of the patient. The patient lies on his/her back.
The cranial hand rests on the right half of the chest, ventrolaterally on the lower ribs. The fingertips point towards the xiphoid process.
The caudal hand lies ventrally on the left half of the chest, the hypothenar area resting above the apex of the heart and the middle finger pointing towards the jugular notch of the sternum.

Execution:

While the cranial hand of the therapist establishes a contact with the liver, the caudal hand feels for the heart.
During this technique, it is not so important to feel liver and heart *per se*, but rather their spatial position: the therapist tries to sense tensions of the liver capsule and of the pericardium and their suspensions.
The therapist follows both of these tensions with his hands, separately, until the movements come to a halt, usually in an area near the middle between the two.
In this moment, a stillpoint can be felt which should be held until a new movement is perceptible in both hands, with the same strength, which might be most adequately described as a moving apart of the two organs.

Effect:

The major effect is a deepening or re-establishing of the thoraco-abdominal balance.

Since one hand absorbs the tensions of the liver sac and the other the tensions of the pericardium, the acting forces unite right in the middle between the two organs, finding nothing but the diaphragm, which, after all, is joined to the liver sac (facies nuda) as well as to the pericardium (on the frontal lower part with the tendinous center).

In addition to these anatomical facts, which render this technique an indirect diaphragmal technique, we find confirmation in the embryologic development of the diaphragm. I should mention at this point that the sternocostal part of the diaphragm develops from the mesenchyma of the transverse septum, the pleuroperitoneal membrane and the mesenchyma of the chest wall's somatopleure. The middle part of the diaphragm (around the openings) develops from the continuation of the gastrohepatic part of the lesser omentum and the dorsal mesentery, and the lumbar part from the mesenchyma enveloping the abdominal aorta and the mesenchyma of the dorsal body wall's somatopleure.

Note:

1.) The application of this technique should be preceded by an examination of the spine and the chest bones in order to exclude or correct mechanic blocks.

2.) This technique should not be applied immediately after a direct mobilization of the diaphragm. The tissue should be given time to rest.

9. A short introduction to existing osteopathic techniques for the heart

In this section, I would like to provide a little overview of existing techniques. How and where is it possible to take influence on the heart? I don't intend to teach the individual techniques, I rather mean to provide a list of possible techniques, the exact execution of which should be learned from specific literature and/or a teacher.
The list of techniques below doesn't pretend completeness. However, it draws on current osteopathic literature.

First of all: osteopathic literature describes techniques for the pericardium and its ligaments on the one hand, and indirect techniques on the other hand. There is no description of techniques specifically for the heart.

Indirect techniques are all techniques that are applied on the osseous-muscular frame of the thorax as well as the techniques working via influence on the nervous system.
These techniques are: mobilization of the diaphragm, ecoute of the diaphragm, mobilization of the chest section of the spine, of the thoraco-abdominal transition and of the cervicothoracic transition, opening of the upper thoracic aperture, mobilization of the claviculae and of the sternoclavicular joints, ecoute of the sternum and mobilization of the ribs and the muscles. Stretching of the neck fascies is also an indirect technique (refer to Barral J.P., Mercier P.; 1988).
All of these techniques have a strong influence on the intrathoracic structures. This is understandable given the fascial relations and the general disposition of the frame: If the outer frame is restricted in its movements, the restriction may also affect the inner organs and vice versa (refer to Paoletti S.; 1998), not to mention the reflexogenic zones and the reflexion zones of the organs on the individual vertebrae.

The indirect techniques are also techniques taking effect on the sympathic and the parasympathic nerve, with the intention of influencing the cardiac plexus.
These techniques, in more detail, are techniques to mobilize the spine of the neck (sympathic) and the vagus nerve (parasympathic), especially cranial techniques. The work via the nervous system is supposed to influence rhythm such as vasoconstriction (refer to Laudon G.; 1904).
The stimulation of the lymphatic drainage is also an indirect technique (refer to Kuchera M., Kuchera W.; 1994).

The other, more direct, techniques are executed on the pericardium and its ligaments.
In detail, they consist of general stretching of the median septum (refer to Barral J.P.; 1991) as well as special stretching of individual ligaments, such as the sternopericardiac ligaments and the vertebropericardiac ligaments (refer to Ligner B.; 1995).
These techniques work essentially by loosening tensions within the fasciae and allow the pericardium to move more freely.

By means of a summary, I might say that the techniques described above all take an influence on the heart in its sac, be it through a general mobilization, a special ligamentous relaxation or by stimulating the nervous conduction. They all mean to take an unspecific effect, generally improving the original situation in order to establish a basis that is less restricted in its movements.

Fig. XLVIII. The fibrous skeleton of the heart

10. Summary

My heart, in this stream
Do you now recognize your image?

(Winterreise op. 89 D 911; Franz Schubert; text: Wilhelm Müller; translation: Celia A. Sgroi;)

The heart, this most beautiful of all structures (refer to Groddeck G.; 1990), has, as we have seen, in addition to its coating, the pericardium, and its muscles, also a core, an inner being: the fibrous skeleton of the heart.
Knowing the characteristics and the significance of this heart within the heart gives everyone the opportunity to expanse their osteopathic practice.

To seize what is flowing, to feel the densened connective tissue in all its movements, to re-live the development of the dense areas and to establish the interaction between the heart's core and the surrounding structures - those are topics that have been discussed in this study and that could be points of departure for new studies and findings.

As I have tried to show, it is possible to grasp, to feel, to seize and to touch this three-dimensional continuum in which time and space have a spatial image.
With our hands and in our osteopathic thinking, we can make room for the organ that gives us life: the heart.

And since the heart is not just a muscle that contracts rhythmically in its sac, but since it has a structure that makes the heart the functional entity it is, we have to make this structure the basis of further osteopathic reflections. Thus, the heart should be included in the osteopathic range of action which is so rich and manifold, already.

11. Appendix 1

Carnegie stages (according to O´Rahilly),
including the development of the heart

Stage 1		fecundated ovum
Stage 2	2-3 days	Segmentation. Differentiation in outer and inner cells.
Stage 3	4-5 days	Free blastocyste. Embryo- and trophoblast. Blastocyste cavity. Separation of the pellucid zone.
Stage 4	5-6 days	Attachment and implantation collapse. Start of invasion.
Stage 5	7-12 days	0.1-0.2 mm. Implantation. Diploblastic embryonic disk. Blastoderm. Amnionic cavity and primary yolk sac.
Stage 6	13-15 days	Extraembryonic mesoderm. Chorionic cavity, chorionic villi. Secondary yolk sac. Primitive streaks. Embryonic mesoderm. Prechordal plate. Body axes.
Stage 7	15-17 days	0.4 mm. Notochordal process. Connecting stalk and allantoid membrane. Building of blood and vessels. Cardiogenic zone.
Stage 8	17-19 days	1.0-1.5 mm. Primitive cavity. Chordal canal. Neurenteric canal.

Stage 9	19-21 days	1.5-2.5 mm. Neural foldings. Cardiac primordium. Cardiac looping. First heartbeats. 1-3 somites. Folding of the yolk sac.
Stage 10	22-23 days	2.0-3.5 mm. Neural folds unite. 2 Pharyngeal arches. Optic grooves. Atrioventricular sulcus. 4-12 somites.
Stage 11	23-26 days	2.5-4.5 mm. Closing of the rostral neuropore. Optic vesicles. Thyroid gland. 13-20 somites.
Stage 12	26-30 days	3.0-5.0 mm. Closing of the caudal neuropore. 3 pharyngeal arches. Forelimb buds. 21-29 somites.
Stage 13	28-32 days	4.0-6.0 mm. Hind limb buds. Optic placode. Otic vesicles. 30 somites.
Stage 14	31-35 days	5.0-7.0 mm. Lens pits. Optic cups. Endolymphatic duct. Face-heart contact. Cardiac jelly within the AV sulcus.
Stage 15	35-38 days	7.0-9.0 mm. Cerebral vesicles. Lens vesicles. Nasal pit. Antitragus. Hand plate. Start of the differentiation of the cardiac valves.

Stage 16	37-42 days	8.0-11.0 mm. Nasal cavity turns to a ventral direction. Auricular tubercle. Foot plate. Aortic valve rotates to a position next to the AV-valves. Primordium of the AV conduction system.
Stage 17	42-44 days	11.0-14.0 mm. Relative growth of the head. Stretching of the torso. Eye-nose groove. Finger rays. Baby teeth. Thymus gland. Spleen.
Stage 18	44-48 days	13.0-17.0 mm. Eyelids. Tip of the nose. Nipples. Toe rays. Starting ossification (clavicula). Physiological umbilical eventration.
Stage 19	48-51 days	16.0-18.0 mm. Lengthening and stretching of the torso. Fusion of the semilunar with the AV region.
Stage 20	51-53 days	18.0-22.0 mm. Elbows flexed.
Stage 21	53-54 days	22.0-24.0 mm. Inversion of hands and feet.
Stage 22	54-56 days	22.0-28.0 mm. Eyelids and outer ear fully developed.
Stage 23	56-60 days	27.0-31.0 mm. Head rounded. Body and limbs developed.

12. Appendix 2

Axis positions

Determined with an ECG

40 ms after the start of the ventricular excitation, the vektor of the momentum becomes manifest, mostly through excitation of the apex and the side walls.

At this point, it is at its maximum, constituting the electric axis of the heart.

Its projection onto the sides of the Einthoven‘s triangle causes the R wave in the latter.

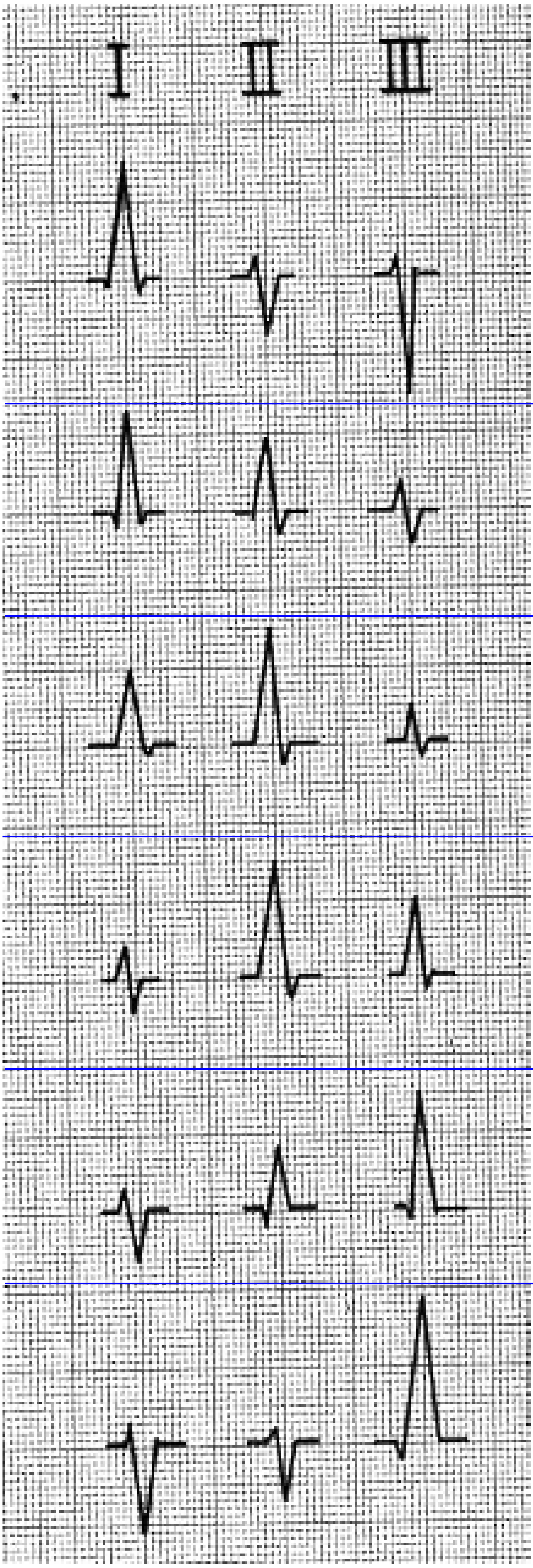
It is crucial to determine the direction of the main vector.

Under normal conditions, the main vector correlates approximately with the anatomical axis of the heart.

By projecting the largest diameter of the vector‘s curve to the frontal plane, the electric heart axis shows in the limb recordings. It defines the axis range of the ECG and is variable by the vector curve turning to the right or left.

To interpret the ECG, the QRS complexes of the limb recordings I-III are compared to each other and the relation of the R waves is established, e.g., R I > R II => left axis deviation.

A schematic interpretation of an ECG would therefore look like this:



Excessive left axis deviation:
usually pathological (left anterior hemiblock (LAH) following myocardial infarction, myocarditis, diphteria); in pyknics with additional adiposity or hypertension; acquired heart vitia, aortopathy with coronary insufficiency, posterior myocardial infarction, Wolff-Parkinson-White syndrome, ASD.

Left axis deviation:
In adults, especially over 40 years of age, adiposity, diaphragmatic eventration, left-ventricular hypertrophy.

Middle range:
Normal position in the healthy adult; in newborns pathological.

Vertical heart:
Possible indication of right ventricle overstrain (organic heart defects, emphysema)

Right axis deviation:
Normal in healthy toddlers; later possible indication of right ventricle overstrain (mitral stenosis, cor pulmonale), condition after lateral myocardial infarction.

Excessive right axis deviation:
Always pathological (right ventricular hypertrophy in the case of organic heart defects; major lateral myocardial infarction; left posterior hemiblock, dextrocardia)

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14. Index of illustrations

Illustrations marked with °°° are all photographs from the dissections done in USA, WV, osteopathic school for osteopathic medicine. (1997)
The original specimen are registered there.

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