nerve and vessels, left pleura, and inner surface of left lung.

The *posterior surface* (Fig. 2556) is called the base in text-book descriptions. It is four-sided, convex, vertical,

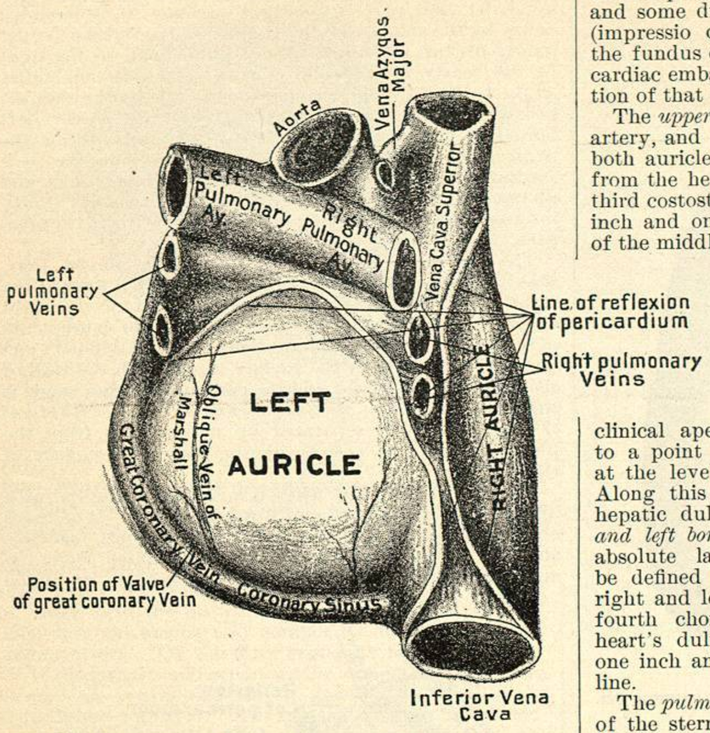

FIG. 2556.—Posterior Surface of the Heart. W. Keiller ad naturam del.

and directed backward. It is formed by the left auricle, and by the portion of the right auricle which joins the two venæ cavæ, and is bounded below by the inferior vena cava and coronary sinus, above by the right pulmonary artery, on the right by a fairly defined border joining the two venæ cavæ, and on the left by the left pulmonary veins and great coronary vein. It is only partially invested by the visceral layer of the pericardium. *Relations* (Fig. 2547): It is separated by pericardium from the bronchi, œsophagus, vagi, descending aorta, vena azygos major and thoracic duct.

The *inferior, diaphragmatic surface or true base* (Fig. 2557) is quadrilateral, slightly convex when the ventricles are distended or in systole, slightly concave when they are relaxed and empty. It is directed downward and a little backward and toward the right, and is bounded by rather sharp and well-defined borders. It includes a small portion of the right auricle and opening of the inferior vena cava, the rest of the surface being about equally divided between the right and left ventricles.

Behind the inferior vena cava is seen a small portion of the left auricle. It presents the inferior extremities of the right and left auriculo-ventricular grooves, and the inferior interventricular groove. *Relations* (Fig. 2546): It is separated by the central tendon of the diaphragm and some diaphragm muscle from the superior surface (impressio cardiaca) of the liver. Its close relation to the fundus of the stomach will help to account for the cardiac embarrassment apt to be caused by acute distention of that viscus.

The *upper surface* gives origin to the aorta, pulmonary artery, and superior vena cava, and is partly formed by both auricles, especially the left. These vessels spring from the heart on a level with the upper margin of the third costosternal articulation, along a line extending one inch and one-half to the left and one inch to the right of the middle line.

Superficial indications (Fig. 2546): The *upper limit* of the heart has just been indicated. The *clinical apex*, or apex beat, is felt between the fifth and sixth ribs, three and a half inches to the left of the middle line. The *antero-inferior border* is indicated on the chest wall by an oblique line, slightly convex downward, extending from the clinical apex on the left, across and slightly upward to a point one inch to the right of the middle line at the level of the sixth chondro-sternal articulation. Along this line the cardiac blends insensibly with the hepatic dulness. These lines being drawn, the *right and left borders* of the heart's anterior surface or the absolute lateral limits of the heart's dulness will be defined by convex lines joining respectively their right and left extremities. Thus, on a level with the fourth chondrosternal articulations, the area of the heart's dulness extends three inches to the left and one inch and three-quarters to the right of the middle line.

The *pulmonary* and *aortic valves* lie behind the left half of the sternum on a level with the lower border of the third costal cartilage. The *right auriculo-ventricular* opening lies behind the sternum on a level with the fourth intercostal space and fifth cartilage. The *left opening* is a little higher and more to the left. (Compare Figs. 2546 and 2548, it being remembered that the surface represented in Fig. 2548 lies obliquely so as to point very decidedly toward the right).

In children the heart is relatively broader and projects more to the left than in the adult, and the apex beat may be in line with the nipple or external to it.

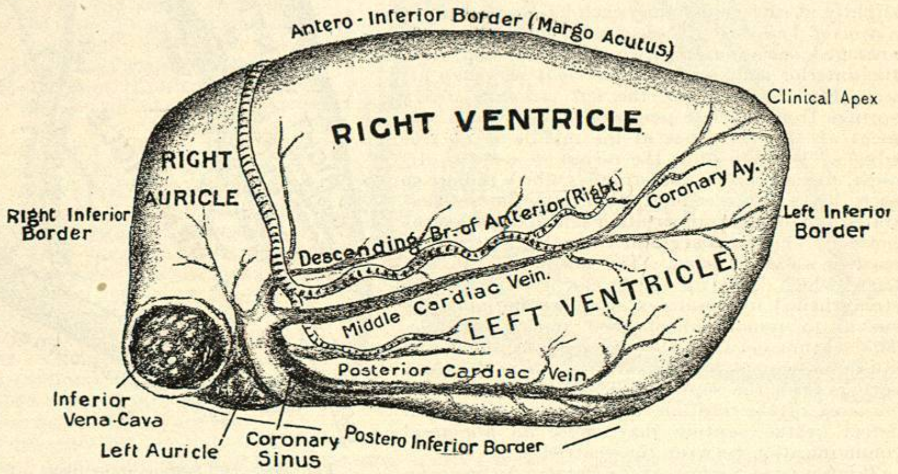

FIG. 2557.—Inferior Surface of the Heart. W. Keiller ad naturam del.

Structure of the Heart.—The heart is invested externally by a fibro-serous membrane, the *epicardium*, under which

lies, especially along the interventricular and auriculo-ventricular grooves, a variable amount of fat with the main trunks of the cardiac vessels embedded therein. Its cavities are lined internally by a smooth endothelial lining, supported by a delicate fibrous membrane (the *endocardium*); the main substance of the heart is composed of muscular tissue (*myocardium*), the intricate arrangement of whose fibres will be found described under the heading *Circulation of the Blood* (Vol. III., p. 105). The valves are avascular and composed of fibrous tissue with an endocardial lining; while in the region of the ventricular orifices are fibrous rings, and between the aorta and auriculo-ventricular orifices there is a central fibro-cartilage.

Blood-Vessels of the Heart.—The *right coronary artery* (Figs. 2548, 2553, and 2557) arises from the anterior sinus of Valsalva, passes forward between the pulmonary artery and right appendix, and follows the right auriculo-ventricular groove till it reaches the inferior interventricular groove where it divides into two branches, of which the smaller *transverse* or *auriculo-ventricular* branch continues in the left auriculo-ventricular groove for some little distance, and the larger *descending* (or better, *interventricular*) branch follows the inferior interventricular groove, supplying both ventricles and the septum. This vessel in its course supplies the right auricle and ventricle, aorta and pulmonary artery. Besides the terminals it gives off two named branches, an *infundibular* branch to the front of the right conus arteriosus, and a *marginal* branch which follows the antero-inferior border to the apex. The *left coronary artery* (Figs. 2553 and 2555) arises from the left sinus of Valsalva, passes behind and then to the left of the pulmonary artery, and appears between that vessel and the left auricular appendix. Here it divides into two branches, the *anterior descending* or *interventricular* branch following the anterior interventricular groove to the apex of the heart; the *transverse* or *auriculo-ventricular* branch following the left auriculo-ventricular groove. A considerable marginal branch follows the left anterior border of the heart. It supplies the aorta, pulmonary artery, left auricle, and ventricle. The two vessels anastomose minutely with each other on the heart and with the pericardial and bronchial vessels on the walls of the aorta and pulmonary artery.

The great cardiac or coronary vein, commencing near the apex of the heart (Fig. 2553), accompanies the interventricular branch of the left coronary artery in the anterior interventricular groove; beneath the left appendix it curves backward in the auriculo-ventricular groove and joins the left end of the coronary sinus (Fig. 2556) where its opening is guarded by a valve. Three or four veins, called *posterior cardiac*, but better called left and inferior cardiac veins, course over the left and inferior surfaces of the left ventricle, joining the great coronary vein and coronary sinus. The *middle cardiac vein* (Fig. 2557), commences at the apex of the heart and follows the inferior interventricular groove with the descending (interventricular) branch of the right coronary artery. It joins the right extremity of the coronary sinus. The *small* or *right coronary vein* (Fig. 2557) runs toward the left in the right auriculo-ventricular groove to join the right end of the coronary sinus. The *coronary sinus*, about one inch in length, occupies the inferior extremity of the left auriculo-ventricular groove (Fig. 2557). It receives the veins above mentioned, all of which are guarded by valves where they join the sinus; and empties into the right auricle in front of the inferior canal opening. Its opening is guarded by the valve of Thebesius (Fig. 2550). In addition to the above a small vein, the *oblique vein* of Marshall, runs downward and over the back of the left ventricle to join the coronary sinus (Fig. 2556). This vein is interesting inasmuch as it, with the coronary sinus, represents the left superior cava of the embryo.

The *anterior cardiac veins* are two or three small veins which pass from the anterior surface of the right ventricle directly into the right auricle. They have no valves. Minute veins (the *venæ cordis minimæ*) open directly into the auricle and ventricles.

Lymphatics.—The cardiac lymphatics, found in great number beneath the lining membranes, open into both the right lymphatic and the thoracic ducts. The former are interrupted in a gland which lies between the aorta and the trachea.

The cardiac nerves are described in the article on the *Circulation of the Blood* (Vol. III., p. 113).

William Keiller.

HEART, DEVELOPMENT OF THE.—The vertebrate heart arises in two distinct ways, each of which is intimately associated with the origin of the blood-vessels in general. In the lower vertebrates its first appearance is in the form of a single tube on the ventral median line of the embryo, quite near the head. Fig. 2558 is a section of a salamander embryo in which the heart is just beginning to form. The body cavity, *lh*, is composed of two lateral halves (see *Cœlom*) separated from each other by a median septum. It is in this septum that the heart first makes its appearance. The two layers which contain this septum become separated, and the opening soon becomes lined with a layer of cells, *end*, the endocardium. The cells of the septum surrounding the opening give rise to the muscle walls of the heart.

In higher vertebrates the heart is first formed by the union of two tubes arising from what may be called the outside of the body. Fig. 2559 is a surface view of a young rabbit embryo in which the heart is beginning to form on either side of the body. The omphalomesenteric veins on either side run toward the ventral median line, and later on unite. Their appearance is such, however,

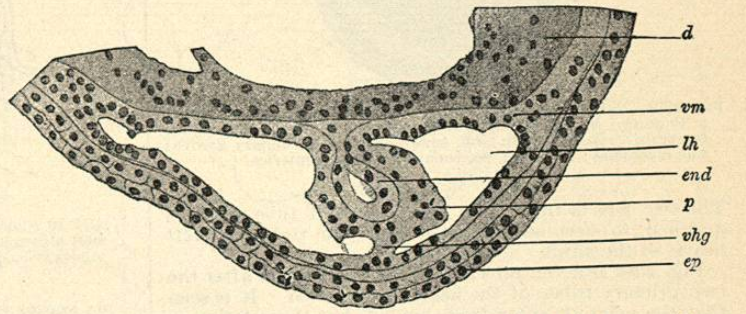

FIG. 2558.—Section through a Salamander Embryo, to Show the Origin of the Heart. (From Hertwig, after Rabl.) *d*, Yolk; *vm*, pericardium; *lh*, body cavity; *end*, endocardium; *p*, muscle layer of the heart; *ep*, epidermis.

that before they are united they may be spoken of as two hearts. Fig. 2560 is from a section through an embryo of the same stage as that pictured in Fig. 2559. The neural canal, *rf*, is just beginning to close, and in the splanchnopleure on either side there is a large fold, *ahh*, which already contains the endothelial tube coming from the omphalomesenteric vein. The tubes grow toward the median lines, but before they unite each has its descending aorta, as shown in Fig. 2561. The rudimentary hearts are formed between the splanchnopleure and entoderm, and as the former surrounds the heart to form its muscular layer the heart protrudes into the cœlomic cavity (Fig. 2560), much as does the single heart of lower vertebrates (Fig. 2558). Soon the two halves unite as indicated in Fig. 2561, and then we have a single heart with two veins entering from behind and two arteries, aortæ, leaving from in front. Although this primary division has nothing whatever to do with the later separation of the heart into its two halves, yet before the two primary hearts are united into a single tube the position of the ventricle is already marked (Fig. 2561, *h*). So, to sum up, in the lower vertebrates the heart appears as a single tube which in general remains such during the life of the animal, and it must be viewed as the primitive form of heart. Higher in the animal scale the heart arises before the foregut is formed, from that portion of the splanchnopleure which later on lies in the median line of the embryo. It is this part which is to give rise to the heart, and in the higher animals the heart arises before the lateral parts have reached the median line (Hertwig).

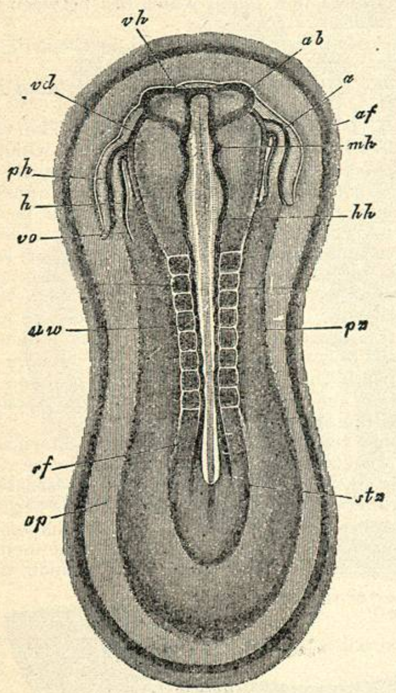

FIG. 2559.—Rabbit Embryo of the Ninth Day. (After von Kölliker.) × 10 times. *h*, Double origin of the heart; *ab*, optic vesicle; *vh*, forebrain; *mh*, midbrain; *hh*, hindbrain; *rf*, medullary groove; *uw*, myotomes; *h*, heart; *vo*, vena omphalo-mesenterica.

The two hearts then unite into a straight tube which is destined to become separated into the right and left hearts of the adult.

Fig. 2562 is a ventral view of two chicks just after the two primary tubes of the heart have united. It is seen that the veins (1) enter from behind, but the relation is soon changed by the heart becoming bent as is already indicated in Fig. 2564.

Fig. 2563 shows the general form of the heart in a very young human embryo. The front of the thorax has been cut away, the incision also extending through the transverse septum and opening the body cavities. The entrance of the veins still lies behind, and the aorta in front, but the heart has already formed one complete loop, making of it an S. Fig. 2564 is a profile of the same embryo, and the heart is indicated as a cast of its cavity. It shows the variations in calibre of the tube throughout its length. At a somewhat later stage the heart is bent upon itself more, and its walls have also become thickened. Figs. 2565 and 2566 are ventral and lateral views of a reconstruction at this stage. The profile view again gives a cast of the heart cavity, which now shows the beginning of the auricle (*V.h.*). At this time the heart is partly tilted over and the veins enter on the dorsal side. Viewed from in front, the auricles, which are just appearing, cannot be seen because they now lie on the dorsal side. A stage later (Figs. 2567 and 2568), the adult form can already be recognized. The heart has undergone a half revolution and has reached the S form. The veins enter nearer the head and the artery arises behind, or away from the head.

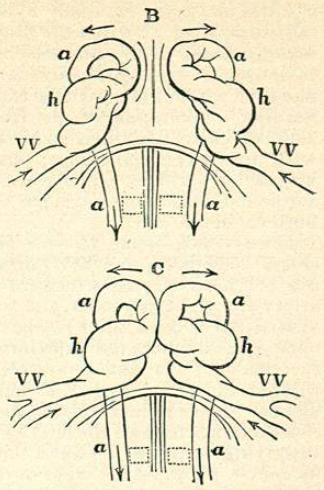

FIG. 2561.—Sketches Showing the more Advanced Condition of the Bitubular Heart of the Rabbit. × 22 times. (After Allen Thompson.) *C* is more advanced than *B*. *VV*, omphalo-mesenteric veins; *h*, heart; *a*, aorta; the arrows indicate the direction of the circulation.

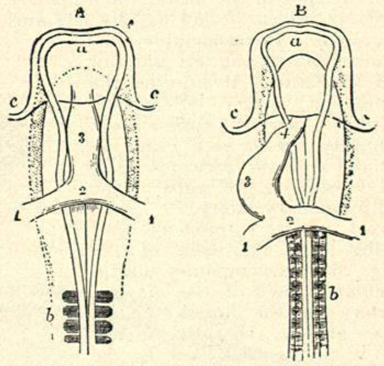

FIG. 2562.—Outlines of the Anterior Half of the Chick Viewed from the Ventral Side, Showing the Heart in its Earlier Stages of Development. × 20 times. (From Quain, after Remak.) *A*, Thirty hours; *B*, forty hours; *a*, anterior cerebral vesicle; *b*, myotomes; *c*, cephalic fold; 1, omphalo-mesenteric veins; 2, 3, 4, the heart.

The aorta lies upon the ventral side and the auricles clasp it from the dorsal. Fig. 2568 shows the great irregularity of the cavity.

A profile view of a heart of this stage is shown in Fig. 2569, which shows the relation of the heart to the surrounding organs. The auricle (*A*) is now in front and the ventricle (*V*) behind. The larger veins enter on the dorsal side by one common opening into the right side of the auricle, the future right auricle.

After the heart has once reached this stage it is only to be separated into its right and left tubes to produce the mammalian heart. In some of the lower animals this never takes place, and in others it is only partial. In cases of arrested development the human heart in the adult may show any of its embryological forms, as, for instance, an open foramen ovale.

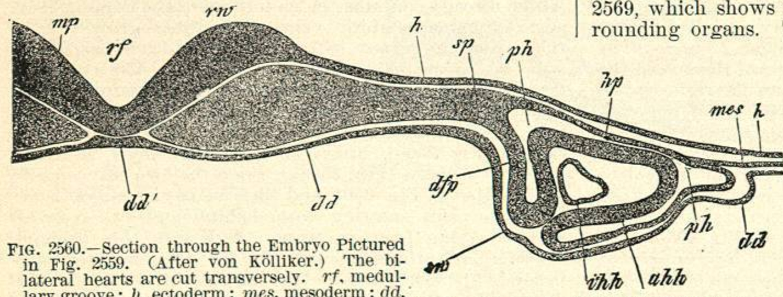

FIG. 2560.—Section through the Embryo Pictured in Fig. 2559. (After von Kölliker.) The bilateral hearts are cut transversely. *rf*, medullary groove; *h*, ectoderm; *mes*, mesoderm; *dd*, entoderm; *dd′*, chorda; *ahh*, muscle wall of the heart; *ihh*, endothelial lining of the heart.

Figs. 2570 and 2571 show the interior of two stages of early human hearts, taken from models made by His. In Fig. 2570, the auricle is enlarged and the vein enters on the right side. The ventricle is considerably smaller and its walls are much thicker than those of the auricle. This is usually the case with the hearts of embryos, as they die with the ventricles contracted and the auricles filled with blood. Between the two there is a narrowed auriculo-ventricular canal and with a corresponding constriction on the outside of the heart. Fig. 2571 shows a more advanced stage. The general state of the heart is much as it is in the Fig. 2570, only that the auricles are "shoved" into the ventricle. This is of considerable importance, as we shall see later on. In both cases the aorta arises from the right side of the ventricle, and in its further development one-half of it must be transferred to the left side in order to produce the aorta proper, while the half which remains becomes the pulmonary artery.

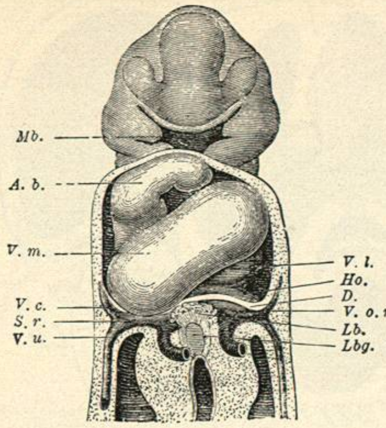

FIG. 2563.

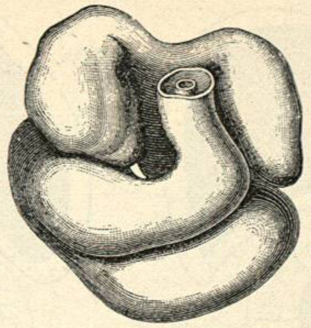

FIG. 2567.

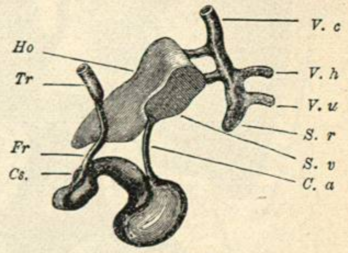

FIG. 2568.

FIGS. 2567 AND 2568.—Ventral and Profile Reconstruction of His' Embryo, Bl. × 40 times. *Ho*, Auricle; *C.a*, auriculo-ventricular canal; *Tr*, aorta.

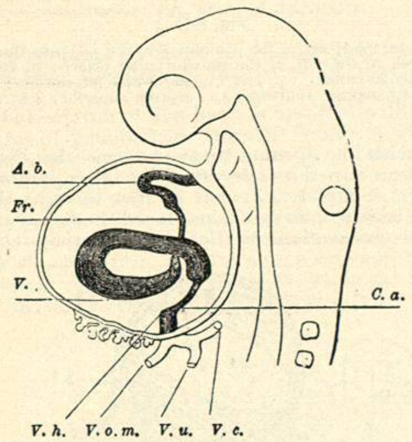

FIG. 2564.

FIGS. 2563 AND 2564.—Ventral and Profile Reconstructions of His' Human Embryo, Lg. × 40 times. (After His.) In the profile view only the outline of the cavity of the heart is shown. *V.*, Ventricle; *A. b.*, bulbus aortæ.

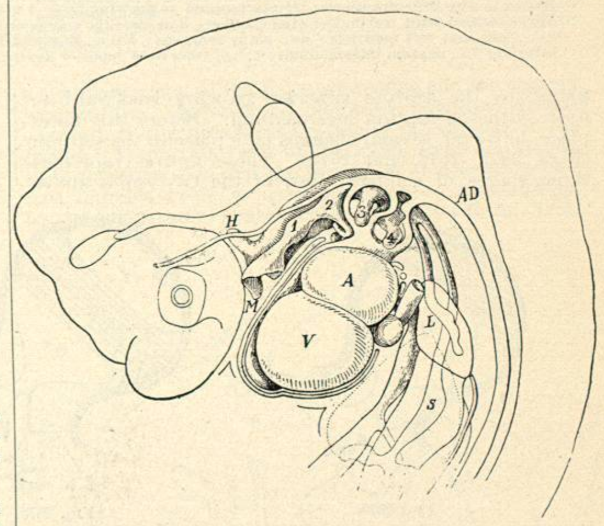

FIG. 2569.—Reconstruction of a Human Embryo enlarged sixteen times, and viewed from the left side. *H*, Hypophysis; 1, 2, 3, and 4, branchial pockets; *M*, mouth; *A*, auricle; *V*, ventricle; *AD*, descending aorta; *L*, lung; *S*, stomach; *P*, pancreas.

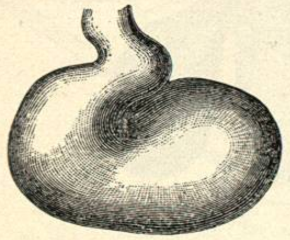

FIG. 2565.

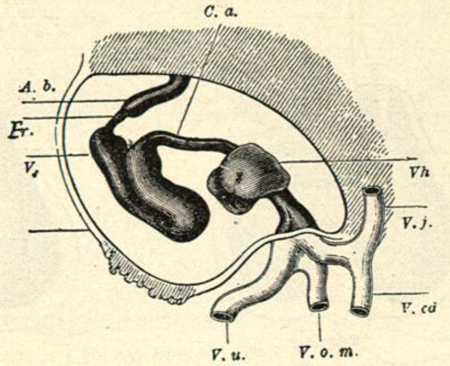

FIG. 2566.

FIGS. 2565 AND 2566.—Ventral and Profile Reconstruction of His' Embryo, Lr. × 40 times. (After His.) *V*, Ventricle; *Vh*, auricle; *A. b.*, bulbus aortæ.

The first important change in the separation of the heart into its two lobes is the formation of two septa, one arising in the auricle, *S.s.*, which grows backward, and one in the ventricle, *S.inf.*, which grows forward. At the same time that these are growing toward each other, a cushion of connective tissue, *s.i.*, is formed upon the two lips of the slit-like auriculo-ventricular opening which aids to complete the septum of the heart. This cushion, or septum intermedium, soon separates the auriculo-ventricular opening into two canals, the right and the left, to become the right and left auriculo-ventricular canals, respectively.

The septum of the auricle is com-

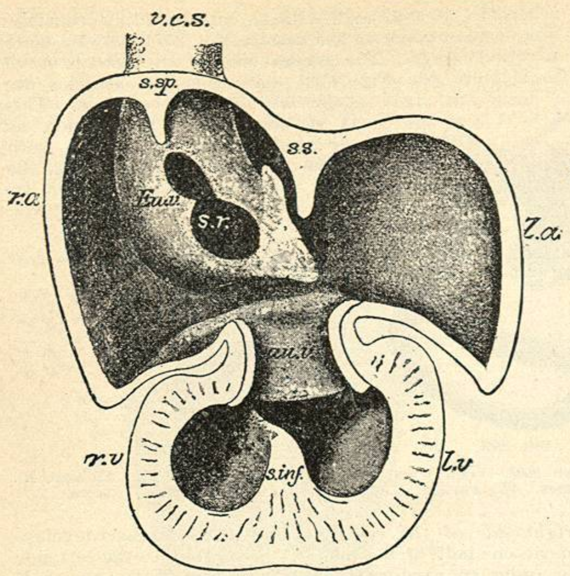

FIG. 2570.

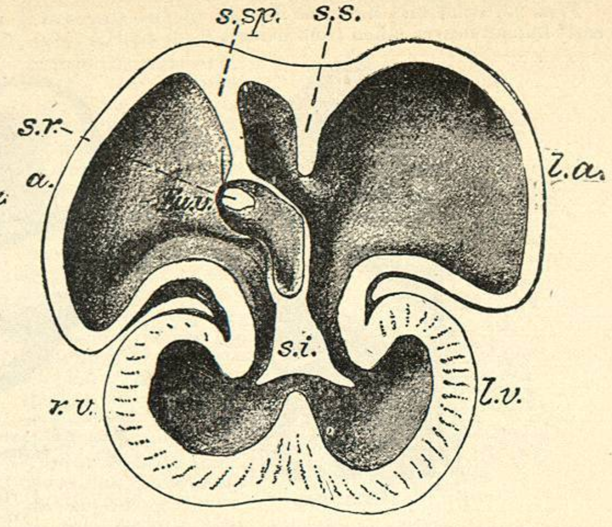

FIG. 2571.

FIGS. 2570 AND 2571.—Two Stages in the Formation of the Septum Intermedium in the Heart of the Human Embryo. (From Quain, after His.) In Fig. 2570 the septum is represented as growing from a triangular area to the left of the sino-auricular orifice; in Fig. 2571 it has coalesced with the endocardial cushions, and lies like a stopper in the auricular canal. *r.a.* and *l.a.*, right and left auricle; *r.v.* and *l.v.*, right and left ventricle; *s.r.*, sinus reuniens; *Eu.v.*, Eustachian valve; *s.sp.* septum spurium; *s.s.*, septum superior; *s.inf.*, septum inferior; *s.i.*, septum intermedium; *v.c.s.*, vena cava superior dextra.

pleted by the septum superior growing backward to unite with the septum intermedium. Before this takes place, however, several changes take place in the septum (Figs. 2572, 2573, and 2574). These figures represent three stages of a lateral view of the two septa above named, with the opening between them. In Fig. 2572, the septum superior is forming, but the S. intermedium is not yet complete. It was at first thought that the opening between them, O', produced the foramen ovale, but later observations by Born showed that there is a

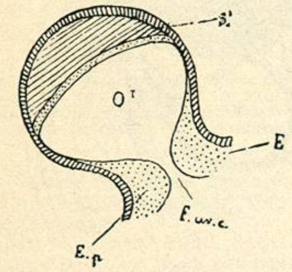

FIG. 2572.

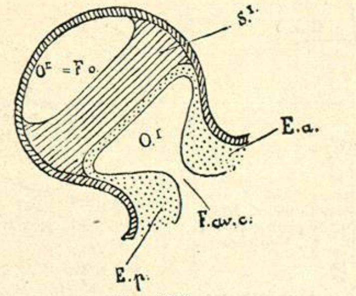

FIG. 2573.

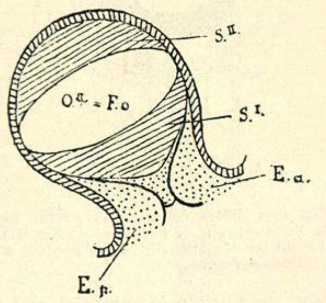

FIG. 2574.

FIGS. 2572, 2573, AND 2574.—Side View of Three Stages, to Show the Formation of the Foramen Ovale. (After Born.) S', First portion of the superior septum: S'', second portion of the superior septum; O', first foramen ovale; O'', secondary opening or true foramen ovale; *E.p.*, endothelial cushion in the auriculo-ventricular opening.

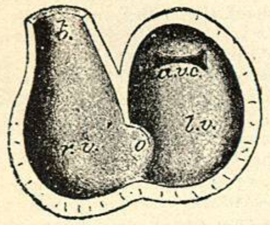

FIG. 2575.

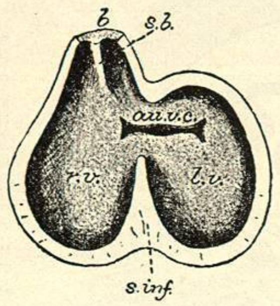

FIG. 2576.

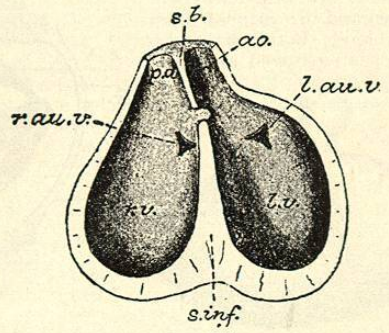

FIG. 2577.

FIGS. 2575, 2576, AND 2577.—Diagrams to Show the Formation of the Septum of the Ventricles and Bulb, and the Mode of Division of the Common Auriculo-ventricular Aperture. (From Quain, after Born.) *r.v.* and *l.v.*, right and left ventricles; *s.inf.*, inferior septum: *b.*, bulb of aorta; *s.b.*, septum bulbi; *au. vc.*, auriculo-ventricular canal; *ao*, aorta; *p.a.*, pulmonary artery.

secondary rupture in the septum superior which is destined to become the true foramen ovale (Fig. 2573, O''). The portion of the septum superior which has been cut off by the formation of the foramen ovale, unites with the septum intermedium as shown in Fig. 2573. The

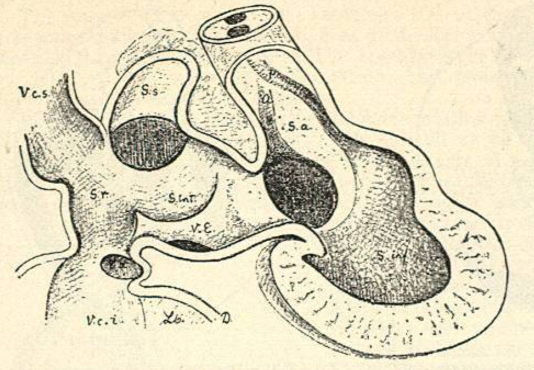

FIG. 2578.—Opened Heart of a Human Embryo Seen in Profile. × 33 times. (After His.) *p.*, Pulmonary artery; *a*, aorta; *S.a.*, septum aorticum; *S.inf.*, septum inferior; *S.s.*, septum superior; *S.int.*, septum intermedium; *v.e.*, Eustachian valve; *S.r.*, sinus reuniens; *V.c.i.*, vena cava inferior; *Lb.*, liver; *D*, diaphragm.

secondary septum, S'', later on forms the limbus of Vieussens, and the first, S, the valve of the foramen ovale.

A partial septum of the heart is first met with in certain classes of ganoid fishes (Dipnoi), where it arises by a union of muscle columns in the auricle. This is a very incomplete septum, which is gradually increased in the amphibia. In neither of these cases has the septum reached the auriculo-ventricular opening. This gives us an auricle partly divided, both compartments communicating with each other, and through a common opening with a single ventricle, much as is shown in the heart of the human embryo pictured in Fig. 2570. In the reptiles the septum is complete, and we have two distinct auricles communicating independently with the ventricle. We can view this as the completion of the second stage, *i.e.*,

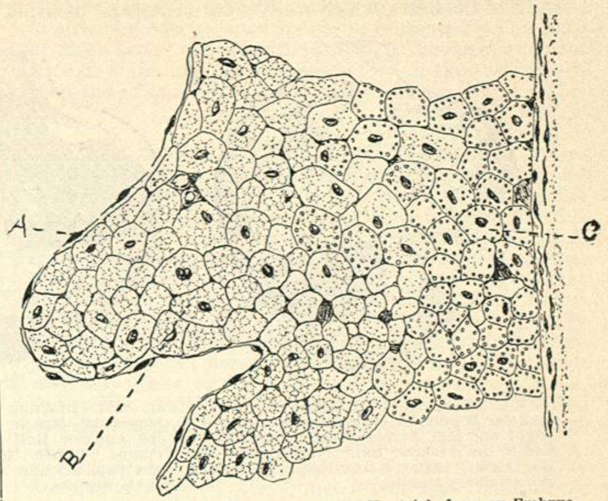

FIG. 2580.—Section of the Wall of the Heart Ventricle from an Embryo Pig 12 mm. Long. (After MacCallum.) The left side of the figure represents the inside of the heart. *A*, Endocardium covering a papillary muscle; *B*, cross section of cells containing a simple network, and therefore very young; *C*, older cells containing fibril bundles.

a complete union of the septum superior and the septum intermedium. In birds and mammals, however, there is a secondary rupture of the septum of the auricle; in the former it is multiple, and in the latter, as a rule, single. It is therefore seen that the formation of a secondary or true foramen ovale, as described by Born, is confirmed by the comparative anatomical evidence (see Born, *Arch.*

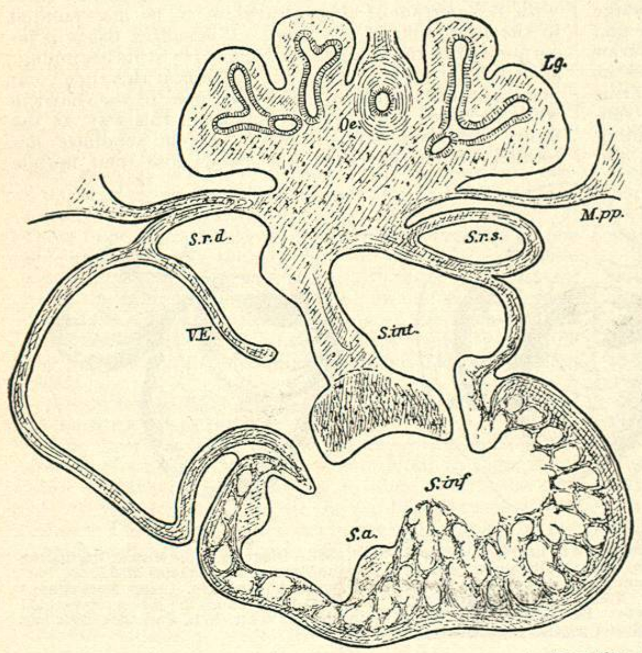

FIG. 2579.—Section through the Heart of a Human Embryo to Show the Formation of the Columnæ Carneæ. × 36 times. (After His.) *Oe.*, œsophagus; *Lg.*, lung; *M.pp.*, membrana pleuro-pericardiaca; *S.r.d.* and *S.r.s.*, right and left horns of the sinus reuniens; *V.E.*, Eustachian valve; *S.int.*, septum intermedium; *S. inf.*, septum inferior; *S.a.*, septum aorticum.

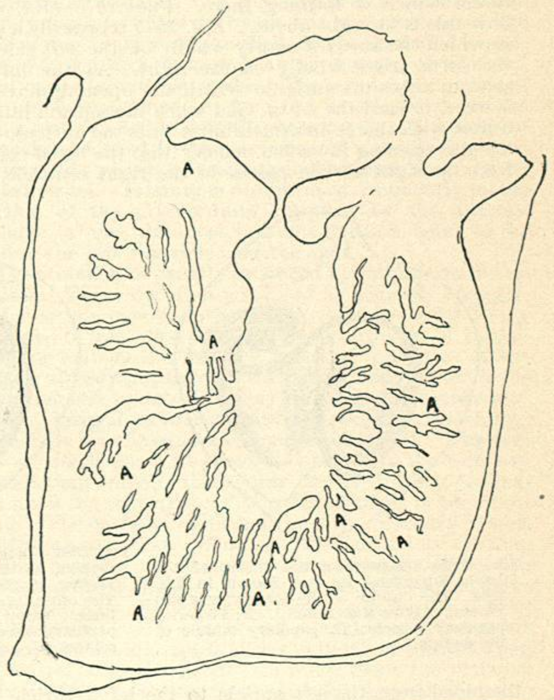

FIG. 2581.—Longitudinal Section of a Heart Ventricle from an Embryo Pig 16 mm. Long. (After MacCallum.) *A*, Position of karyokinetic figures.

f. mik. Anat., Bd. 33, and Röse, *Morph. Jahrbuch*, Bd. 15 and 16).

The opening of the vein is guarded by two folds of the walls of the heart, which really form a complete bicuspid

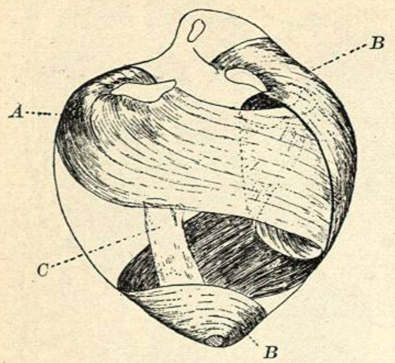

FIG. 2582.—Diagram of the Course of the Superficial Muscle Layers Originating in the Right and Left Auriculo-ventricular Rings and in the Posterior Half of the Tendon of the Conus. (After MacCallum.) *C*, Anterior papillary muscle.

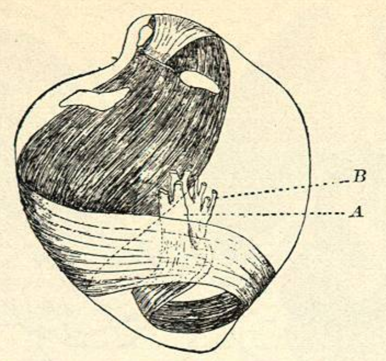

FIG. 2583.—Diagram of the Course of the Superficial Muscle Layers Originating in the Anterior Half of the Tendon of the Conus. (After MacCallum.) *A*, Posterior papillary muscle; *B*, papillary muscle of the septum.

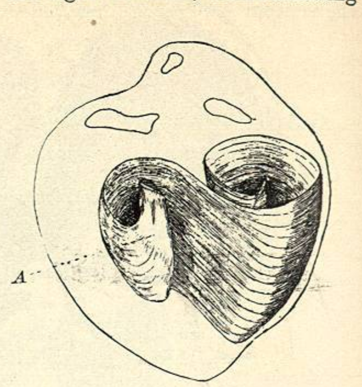

FIG. 2584.—Diagram of the Course of the Deepest Layer of Muscle of the Left Ventricle. (After MacCallum.) *A*, Posterior papillary muscle.

valve (Fig. 2571). An additional fold extends to this from in front, the sectum spurium, *S.sp.* Later on, the orifice enlarges to incorporate a portion of the veins into the auricle, but the right lip of the opening remains permanently as the Eustachian valve. The pulmonary veins are formed later. They grow from the lungs to the left auricle.

Returning to a stage of heart as represented in Fig. 2571, we notice that the common ventricle shows a constriction on the outside which corresponds to a septum forming on the inside. As this septum from the inside, the septum inferius, grows toward the S. intermedium, it must also grow toward the aorta to join a septum aorticum which is forming there. Figs. 2575–2577, show how this is brought about. Fig. 2575 represents a stage in which the auricles empty wholly on the left side and the aorta arises wholly on the right. As the inferior septum arises the auriculo-ventricular opening moves, as it were, toward the aorta; and when the septum inferius unites with the S. intermedium it cuts the auriculo-ventricular opening in such a manner that the blood coming from the right auricle passes to the right ventricle, and

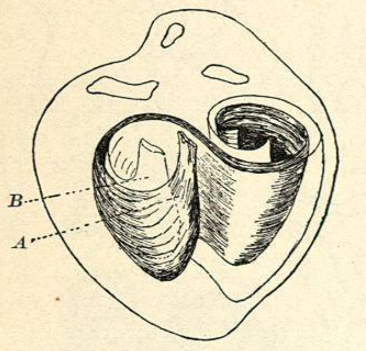

FIG. 2585.—Diagram of the Course of the Layer Superficial to that Shown in Fig. 2584. The outline of the deep layer is also shown. (After MacCallum.) *A*, Posterior papillary muscle; *B*, papillary muscle of the septum.

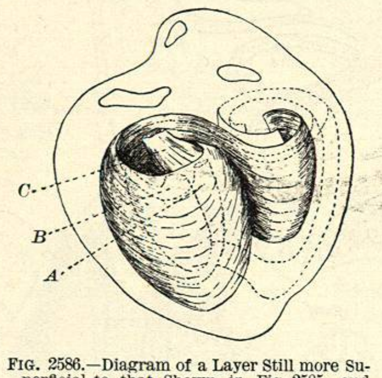

FIG. 2586.—Diagram of a Layer Still more Superficial to that Shown in Fig. 2585, and Ending in the Anterior Papillary Muscle. The other layers are represented in dotted lines. (After MacCallum.) *A*, Posterior papillary muscle; *B*, papillary muscle of septum; *C*, anterior papillary muscle.

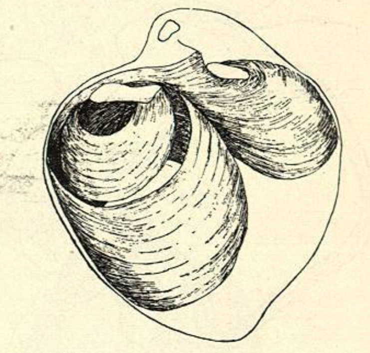

FIG. 2587.—Diagram of the Muscle Originating in the Tendon of the Conus and Upper Part of the Right Ventricle. (After MacCallum.) This layer surrounds the layers represented in the left ventricle in Figs. 2584, 2585, and 2586.

the blood from the left auricle to the left ventricle. A small opening exists for quite a while between the two ventricles, but, later on, this is closed by a membrane of connective tissue. Before the ventricles are completely separated from each other, a view of the septum appears much as is shown in Fig. 2578. The aorta is already completely separated into two vessels: the one which communicates with the right ventricle, communicating above with the fifth aortic arch, and the one from the left with the fourth. The fourth is destined to become the aorta, and the fifth the ductus arteriosus from which the pulmonary artery arises.

At an early stage the tissue of the ventricle walls becomes spongy on the inside. These meshes and columns play a very important part in the formation of the valves, muscle columns, and the tendons to the valves. We have seen that the septum intermedium is formed in the auriculo-ventricular canal and divides it into a right and a left half. When this is complete a section of the heart gives a picture as shown in Fig. 2579. At the same time a portion of the auricle is, as it were, pushed into the ventricle, as the figure shows. This invagination takes with it a portion of the epicardium, to be incorporated in the formation of the valve. Connective tissue is incorporated in the formation of the valve at its beginning, although the great bulk of the valve is at this time composed of muscular fibres. The burrowing of the ventricle walls includes also the valves, and in this way, as the figure indicates, the primitive chordæ tendineæ are formed. Soon, however, the bands lose their muscle fibres, in the portions which form the chordæ, and in other portions, farther away from the valve, the muscle fibres increase to form the papillary muscle. The valves have therefore a double origin: (1) Peripheral, and (2)

from the septum intermedium. According to His, the tendons attached to the valves arising from the periphery, have their permanent attachment to the valve from the beginning, while a portion of those passing to the valve and arising from the septum intermedium may possibly shift their valvular attachment.

The muscle walls of the two ventricles are at first of the same thickness, but, later on, that of the left becomes heavier than that of the right. The spongy layer in the ventricle is covered with endocardium, and from this layer the columnæ carneæ arise.

Recently MacCallum has made extensive studies on the development of the heart muscle cells as well as of the arrangement of the fibre bundles in the hearts of embryos.* MacCallum has found that the heart muscle cell in its development undergoes certain changes by which younger and newly developed cells can be distinguished from fully developed cells. The difference between the older and younger cells is well shown in Fig. 2580, taken from the heart of a very young pig's embryo. It is seen that the younger cells are immediately under the endocardium and that the older cells have been pushed toward the outside and lie immediately below the pericardium. In the younger cells the nuclei multiply by indirect cell division and the distribution of such cells is shown by the letter *A* in Fig. 2581. Here again the growing point of the muscle of the heart is found to be immediately below the endocardium. It appears then that the growth of the heart after the organ is well formed is on the inside immediately below the endocardium. In some way, not yet definitely known, the heart is then gradually rolled up, becoming more and more complex in the higher animals. MacCallum has succeeded in unravelling the musculature in the embryo pig and the human fœtus before the fibres have become interlaced too much. According to him, the fibre bundles can be divided into four groups: (1) Those arising from the auriculo-ventricular ring on one side and passing to the papillary muscle of the opposite side (Figs. 2582 and 2583); (2) those bundles arising from the papillary muscles on one side and passing to the papillary muscles on the opposite side (Figs. 2584, 2585, and 2586); (3) those fibres arising from the auriculo-ventricular ring on one side and passing to the auriculo-ventricular ring of the opposite side (Fig. 2587); and (4) those fibres which simply encircle the left auriculo-ventricular ring and the aorta (Fig. 2588).

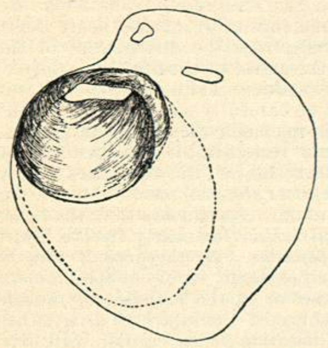

FIG. 2588.—Diagram of the Layer of Muscle Surrounding the Aorta, and Left Auriculo-ventricular Ring. (After MacCallum.) Fig. 2587 is represented in dotted lines.

According to MacCallum, the points to be emphasized in his work are as follows:

The heart consists of several layers of muscle, the course of which is shown in some detail in Figs. 2582–2588. Nearly all begin in the auriculo-ventricular ring of one ventricle and end in the papillary muscle of the other. Those fibres which begin near the outside of one ventricle end near the inside of the other ventricle.

The thin superficial muscle being removed, the left ventricle can be unrolled so that its cavity and papillary muscle are exposed. This shows it to be a flat band of muscle continuous with the muscle fibres which cross over in the septum from the right ventricle.

Grouping these layers together, it is plain that the heart in the embryo is a scroll-shaped band of muscle with tendons at each end. As it grows older the layer of muscle passing over in the septum from the right to the left ventricle remains comparatively thin, while the ventricular cells increase greatly in thickness. The place of most active cell growth is near the inside of the ventricular walls, and they are, therefore, at the two ends of the band of muscles making up the heart.

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* MacCallum: Anat. Anz., xiii., 1897; Journ. of Experimental Medicine, iv., 1899; and Welch Festschrift, Johns Hopkins Hospital Reports, ix., 1900.

HEART DISEASES: ACTINOMYCOSIS.—Actinomycosis of the heart has been observed a number of times within recent years, and it is very probable that as the reported cases of infection with actinomyces multiply this organ will be found to be not infrequently affected. Since the respiratory tract appears to be one of the most common avenues of entrance of this parasite, secondary involvement of the mediastinum is of frequent occurrence, whereby extension to the pericardium is very likely to take place. Besides infection by direct extension from the mediastinum hæmatogenous metastases in the heart wall may occur, or the heart may be primarily affected, the avenue of entrance being unknown. Paltauf found extensive actinomycosis of the wall of the right ventricle in a tuberculous subject, the condition having been diagnosed as tuberculous pericarditis. In cases observed by Israel, Ponfick, and others, metastases were found in the heart arising from primary foci in the liver, lungs, and other parts of the body (pyæmic actinomycosis). Occasionally a general infection of the body, acute or chronic, occurs, and the heart is involved in common with other organs. Actinomycosis of the heart presents no definite clinical picture. The diagnosis of the condition will rest entirely upon the demonstration of the presence of the parasite within the body. The treatment should be directed along general lines, with the internal use of potassium iodide, which in some cases has appeared to have a specific effect upon the fungus.

Aldred Scott Warthin.

HEART DISEASES: ANÆMIC INFARCTION.—The occlusion of a branch of a coronary artery, if not immediately fatal, is followed by an anæmic necrosis of the part of the heart wall supplied by the occluded vessel. The necrosed area is known as an anæmic or white infarct or as *myomalacia cordis.* The terminal branches of the coronary arteries are true end arteries, and possess but a very limited collateral anastomosis. The area of necrosis produced by the occlusion of a terminal branch corresponds to the physiological distribution of the affected vessel. Infarction occurs most frequently in the portion of the myocardium supplied by the anterior coronary artery, the most common location being in the wall of the left ventricle near the apex.

The occlusion is usually produced by thrombosis or embolism. These events are favored by sclerotic changes; under certain conditions cororonary sclerosis in itself may give rise to infarction without the occurrence of thrombosis or embolism. In such cases the nutrition of the muscle already impaired by the partial obstruction of the vessel caused by sclerosis may be so much further lowered by general circulatory disturbances that the integrity of the muscle can be no longer preserved. Thrombi are of much more frequent occurrence in the coronary vessels than emboli; their formation is directly dependent upon the occurrence of sclerotic changes in the vessel wall. The entrance of emboli into the coronary vessels is of rare occurrence. This fact is explained by the anatomical peculiarities of the coronary arteries, the location of their orifices, angle of divergence with the aorta, force of current, etc. Embolism, however, occasionally occurs; the embolus usually consists of a portion of a thrombus primary in the left heart, either parietal or formed upon the mitral or aortic valves. In other cases the embolus may consist of atheromatous material derived from the vessel wall above the point of occlusion. Septic emboli occur in cases of malignant endocarditis; they are more frequently derived from vegetations on the mitral than