Observations on the structure and connexions of the valves of the human heart / by W.S. Savory.

OBSERVATIONS

ON THE

STRUCTURE AND CONNEXIONS

OF THE

VALVES OF THE HUMAN HEART.

By W. S. SAVORY,

TUTOR AT ST. BARTHOLOMEW'S HOSPITAL;
SURGEON TO THE ROYAL GENERAL DISPENSARY, ETC.

OBSERVATIONS,

&c. &c.

The following paper contains the results of various observations on the anatomy of the auriculo-ventricular and arterial valves. It has been my endeavour to avoid all useless repetition of that which is already generally known and accurately described. Previous observations are repeated or alluded to only so far as they appear necessary to the explanation of my own. The dissections have not been entirely limited to the human heart, but have been extended only to illustrate and determine any points that were otherwise doubtful or obscure.

The two auriculo-ventricular orifices are situated upon the same plane at the posterior portion of the base of the ventricles; they are directed obliquely downwards and backwards, the walls of the ventricles extending higher in front than behind. They are separated from each other by the upper border of the septum of the ventricles. In the angle formed between these orifices in front, the aortic aperture is situate,—more closely connected, however, with the antero-lateral portion of the left auriculo-ventricular ring, and separated from the right by a thin border of muscular tissue. Its close connexion with the left side will be presently more particularly examined. This orifice is placed horizontally.*

* In the above description, the apex of the heart is supposed to be directed downwards.

Lastly, in front of the aorta, the pulmonary artery arises. This orifice lies obliquely, looking upwards and to the left, and is on a plane superior to the aortic aperture. This is the result of the infundibuliform prolongation of the muscular fibres of the right ventricle upwards, and this disposition is especially marked in the human heart, the muscular tissue being continued upwards to the pulmonary artery higher in man than in any of the animals whose hearts I have more particularly examined,—as the horse, ox, sheep, &c.; otherwise the relative position of the four orifices corresponds very exactly with the arrangement above described. Although at the first glance the aorta and pulmonary artery appear to arise in close connexion with each other, yet, if we dissect down between the two vessels, we shall find them separated at the base by an interval of muscular tissue. The same arrangement occurs between the adjacent portions of the aorta and right auricle; and by a careful dissection continued downwards, we at last arrive at the thin border of the right ventricle between them. Between the adjacent surfaces of the aorta and left auricle, however, no such separation can be effected. The relative situation of the four orifices is easily seen by removing the fat and coronary vessels from the base of the heart, and then cutting off the auricles and great vessels on a level with the base of the ventricles. The two arterial orifices are circular; the auriculo-ventricular apertures are oval, their long diameters being at right angles to each other—*i. e.*, in the left transverse, and in the right from before backwards. After prolonged boiling,* the fat and coronary vessels will separate from the base of the heart with great facility, and the grooves in which the vessels lay are well seen. The arrangement to which their existence is due will be presently examined. With very little care we can separate the auricles from the ventricles; and it is safer to use the handle than the blade of the scalpel for this purpose, for we then run no risk of dividing any fibres: a little more difficulty will usually occur

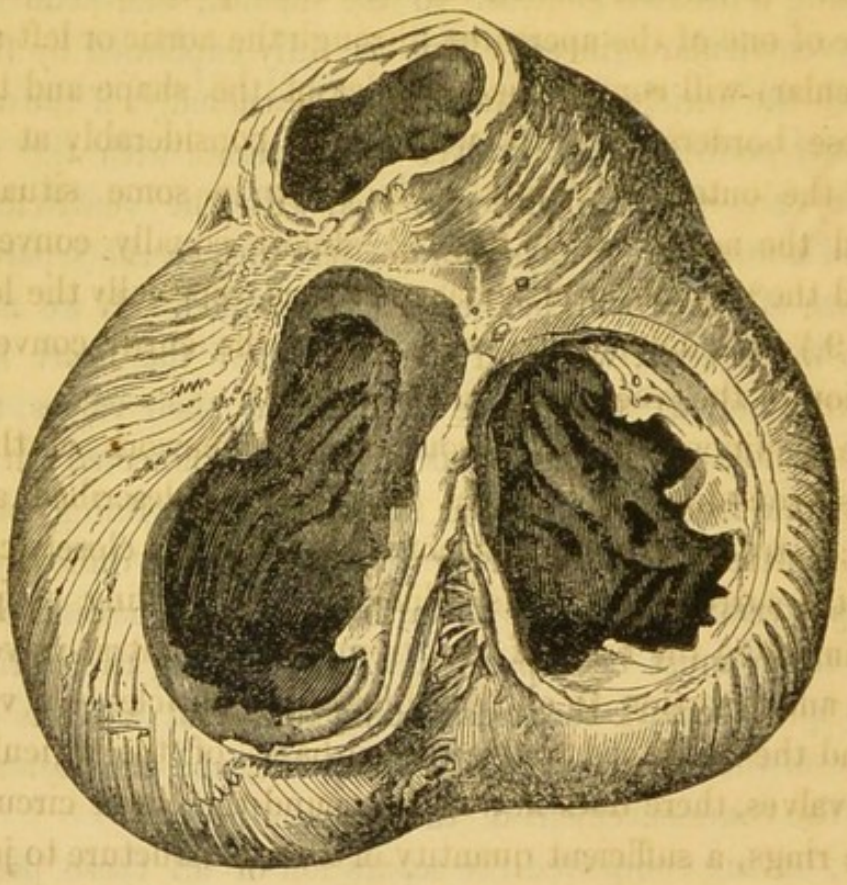
* From one to two hours for a human or sheep's heart, and four or five hours for the heart of a horse or ox. It is a good plan to fill the cavities previously with cotton wool. The heart is prevented from shrinking, (which otherwise it will do,) and its shape is preserved.

at the septum, especially in front, where the auricular fibres are more abundantly attached. The separation being completed, it will be observed that in the auricles the margins of the orifices are rough and uneven; the extremities of the fibres appear as if torn, presenting a decided contrast to the smooth, well-defined border of the ventricular orifices. This is fully explained by the mode in which the auricles are attached. Occasionally, if the operation be hastily performed, the valves will separate with the auricles, but they generally remain connected with the ventricles; their attached borders are always more or less torn in the separation,—the cause of which will be hereafter examined. If we now proceed to the arteries, we shall find (provided the heart has been sufficiently boiled) that these vessels and their valves, together with the whole of the tendinous structures connected with them, will separate from the muscular fibres, the inner lining membrane of the ventricles only requiring division: some difficulty occurs at the posterior part of the aorta, from which a portion of tough fibrous tissue must be separated. In detaching the auricles, we cannot fail to remark the close connexion that subsists between the base of the anterior wall of the left one, and the posterior surface of the commencement of the aorta.

Now, having completed the separation of all these parts from the ventricles, we shall see that there remain indeed only three orifices; that the aortic has become continuous with the left auriculo-ventricular, the posterior part of the one opening as it were into the anterior part of the other; (a portion of the anterior mitral valve only sometimes intervening, which may be removed,) the outline of the two together somewhat resembling the figure 8 (Fig. 1.) The general outline of the base of the ventricles is irregularly triangular, with the apex at the origin of the pulmonary artery; and from the arrangement of the four, or rather three orifices, it is seen that while the auriculo-ventricular, as well as the arterial apertures, are separated one from the other by a rounded ridge of muscular tissue, the posterior portion of the pulmonary orifice is separated from the anterior border of the right auriculo-ventricular ring by a more considerable interval occupied by fibres forming the base of the right ventricle, and having a

general direction from the septum and aortic orifice obliquely outwards to the right.* The margins of the apertures are smooth and well defined; that bounding the pulmonary orifice is thin,

Fig. 1.



but the others are much thicker and convex; and this especially applies to the left auriculo-ventricular border. A close inspection and careful examination of the general arrangement and direction of the muscular fibres (which are well seen in a heart after prolonged boiling) will enable us to understand the formation of these thick convex borders; and it is important, as they are closely connected with the construction and functions of some of the valves. It may now be plainly observed that the fibres forming the walls of the ventricles converge around the rings. We can easily trace them up from the walls of the ventricles, curving obliquely over the convex border, and having their extremities fixed around the orifices. We may remove them layer after layer, and still find the same arrangement to obtain; the deeper layers

* The terms *left* and *right*, &c., apply to the heart.

lying more transversely, and obliquely intersecting those above and below. It is unnecessary now to enter more at length into the arrangement of these fibres, and perhaps enough has been said with regard to the formation of these thick and convex borders. A vertical section through some portion of the circumference of one of the apertures (through the aortic or left auriculo-ventricular) will convey the best idea of the shape and thickness of these borders, both of which vary considerably at different parts, the outer and inner walls being in some situations, as around the aortic orifice, (fig. 2,) almost equally convex, while around the auriculo-ventricular apertures, especially the left, (figs. 8 and 9,) the outer wall forms almost the entire convexity, the direction of the inner being nearly straight.

The tendinous circles (fibrous zones, framework of the heart, &c.) surrounding the orifices are generally described as "firm rings;" structures quite distinct from, although closely connected with, the surrounding parts, which, besides serving as points of attachment to the base of the tricuspid and mitral valves, afford origin and insertion to all the fibres of the auricles and ventricles. Beyond the thickened and attached bases of the auriculo-ventricular valves, there does not exist, around the entire circumference of the rings, a sufficient quantity of fibrous structure to justify the descriptions and terms applied, or the uses ascribed to it. After removing the auricles as before described, there remain delicate fibrous rings surrounding the margins of the auriculo-ventricular apertures, and closely connected with the muscular fibres of the ventricles, denser and more plainly marked on the left side. In the anterior half of the border of the ventricular septum, a considerable portion of dense fibrous tissue is found closely connected at its anterior extremity with the adjacent posterior portion of the commencement of the aorta, and causing the difficulty in its separation, as also of the auricles at this part, before noticed. Spreading out posteriorly between the ventricles, but especially curving round to the posterior portion of the left auriculo-ventricular ring, this fibrous band adds considerably to its thickness. In structure it possesses all the characters of the densest

fibrous tissue. On the opposite side also, a thin but dense portion of fibrous tissue extends from the aorta round the left margin of the ring. More delicate processes of the same structure are generally connected with the aorta, and extend into the muscular substance of the ventricle between the pulmonary artery and left auriculo-ventricular orifice. In separating the vessels, however, from the ventricles, we find that with them we can remove all fibrous structure, leaving an edge of muscular tissue.

Of the three pulmonary valves, one is posterior, one forwards and to the right, and one forwards and to the left. Of the three aortic valves, one is opposite the ventricular septum, one to the left; and one anterior, inclining to the right, corresponds to the muscular substance of the ventricle between the pulmonary and right auriculo-ventricular apertures. Of the tricuspid valves, one corresponds to the ventricular septum, one lies to the right, and the other forwards and to the left. Lastly, of the two mitral valves, one is anterior and somewhat to the right, the other posterior and to the left. The three semilunar valves of each artery are of tolerably uniform size; this, however, is by no means the case with the auriculo-ventricular valves. The posterior mitral valve is smaller and thinner than the anterior, and is more or less deeply cleft in its centre; the division in some cases extends almost to the base, and this valve then consists of two segments. Of the tricuspid valves, the anterior is generally the largest, and the right the smallest segment. The form and arrangement of these valves have been frequently described, and the smaller portions also which are found between the principal segments. Indeed, towards their attached border the valves are continued into each other, so as to form an uninterrupted membranous ring.

Notwithstanding the time and attention which have been bestowed in investigating the structure of the valves of the heart, one very important means of obtaining a clear idea of their construction appears to have been entirely unheeded or overlooked—viz., the plan of making vertical sections through various parts of the four rings. I do not remember to have seen

a preparation, or even a representation of such a section, made with a view to exhibit their structure. Dr. Reid* has given a detailed description of the valves, and has illustrated his remarks by many diagrams, and yet no representation of, or even reference to, a vertical section is given; and this seems the more remarkable, as such drawings would illustrate at a glance many points which can scarcely be rendered clear by the most graphic description.

In a heart from the base of which the fat, cellular tissue, and coronary vessels, have been carefully and completely removed, the walls of the auricles are observed to pass down on to the *inner* surface of the ventricular borders surrounding the orifices, so that the greater portion of their breadth projects externally beyond the outer wall of the auricles, (especially on the left side, where the border is much thicker;) and thus is the deep groove formed in which the coronary vessels of the heart are lodged. (Figs. 8 and 9.) The gradual increase in the size of the arteries towards their termination, the three pouch-like dilatations corresponding to the situation of the valves, and to the sinuses of Valsalva, and the great diminution in the thickness of the arterial coats behind the valves, commencing rather abruptly opposite their upper margin, may now be plainly seen; but as all these characters have been frequently described, it is unnecessary now to dwell upon them. They are all more strongly marked in the aorta. The outline of the arterial tendinous rings may also be observed. These rings, which are plainly seen when the arteries are laid open, are generally described as "formed by a fibrous band or zone, one edge of which is even, and gives attachment to the muscular fasciculi of the ventricle, whilst the other is scallopped into three deep semilunar notches, and is firmly fixed to the middle coat of the large artery. The semilunar margins of the notches just mentioned are much thicker and stronger than the rest of the tissue; and from the small depth of the tendinous zones, the notches descend nearly through to its ventricular edge, almost reaching the muscular substance, which, indeed, is attached

* Cyclopædia of Anatomy and Physiology, art. "Heart."

to the middle of the stout, tendinous, semilunar margins. The middle coat of the artery presents a festooned border, divided into three convex, semicircular segments, which are received into, and attached to, the corresponding notches of the tendinous ring."* Dr. Reid† has given a detailed account of these festooned rings, and describes their appearance differently. He is disposed to regard them as distinct and independent structures, closely indeed connected with, but separable from, the surrounding parts. He says: "Each of these arterial rings appears as if composed of three semilunar portions, placed on the same plane, the convexities of which are turned towards the ventricle, and the concavity towards the vessels. Each of these semilunar portions has its projecting extremities intimately blended at their termination with the corresponding projecting extremities of those next to it, so that the three form a complete circle, with three triangular portions projecting from its upper edge. The semilunar portions approach fibro-cartilage in their structure, and have the intervals left between their convex edges filled with a texture more decidedly fibrous, and which is considerably weaker than the semilunar portions, more particularly on the left side of the heart."‡ From repeated observation, it appears to me that what has been described as the upper and thickened festooned border is the result of the attachment of the bases of the valves to the arterial coat, and is formed by an intimate union of the fibrous tissue composing the valves with the elastic coat of the artery. 1. These festooned rings correspond exactly with the attached bases of the valves; and hence their shape. 2. They are thickest and most strongly marked at the angle formed by the junction of two valves, to which points the bands of fibrous tissue in the valves converge. 3. The microscope shows these festooned rings to be composed of a mixture of the white fibrous with the yellow elastic tissue—an arrangement naturally to be expected from an intimate union of the tendinous tissue of the valve with the arterial coat. The proper tissue of the arterial walls terminates

* Quain and Sharpey's Anatomy and Physiology, p. 1118.

† Cyclopædia of Anatomy and Physiology, art. "Heart."

‡ Op. cit., vol. ii. p. 588.

indeed in these festooned rings, below which it is not found. The muscular fibres of the ventricles are attached to the lowest portion of their convexity, and extend upwards for a short distance into the intervals left between the convex margins of the festoons; thus presenting an undulating border around the base of the vessels; while the upper portion of the space forming the apex of the angle between two valves, which is destitute of muscular fibres, is occupied by a thin layer of white fibrous tissue, containing some few yellow elastic fibres scattered irregularly through it.

If we now make a section through the anterior aortic valve, the view represented in figure 2* is obtained. The aorta and pulmonary artery, (Figs. 2 and 3,) expanding towards their

Fig. 2.

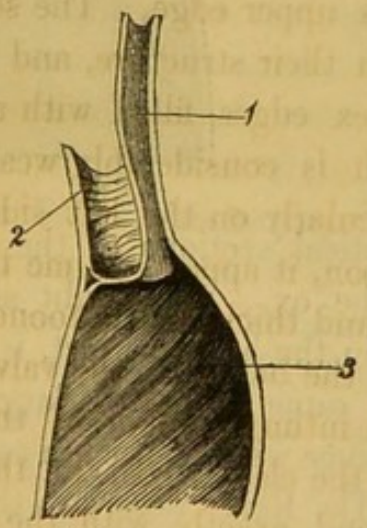
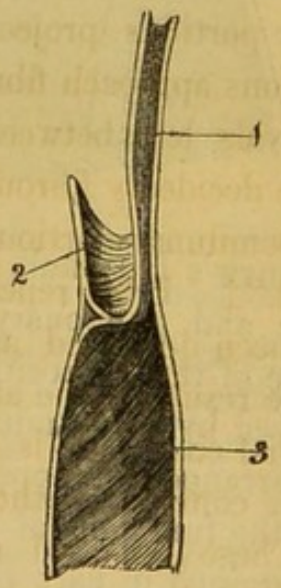


Fig. 3.



1. Section of arterial coat. 2. Section of valve. 3. Section of ventricle.

termination, are situated upon the outer edge of the ventricular border before described; the consequence of which arrangement is, that the portion of valve adjacent to the vessel passes over, and rests upon the muscular substance—is supported upon the inner border of the free edge of the ventricles surrounding the arterial orifices. This arrangement, in consequence of the small size of the parts, is not so obvious at the first glance in the human heart, but can scarcely be overlooked in an examination of the

* These sketches are purposely made somewhat diagramically, in order to show more clearly the relations of parts.

heart of any one of the larger animals. Figures 4 and 5 are accurate sketches from preparations in the Museum of St. Bar-

Fig. 4.

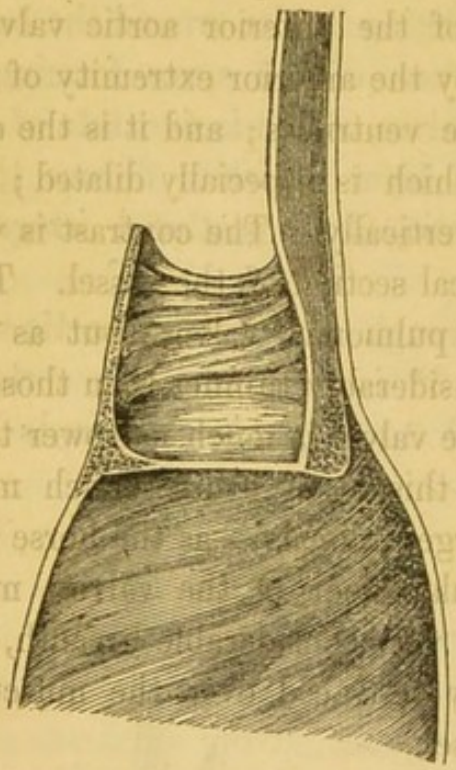
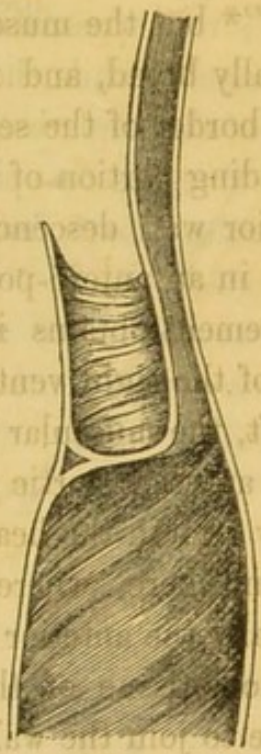


Fig. 5.



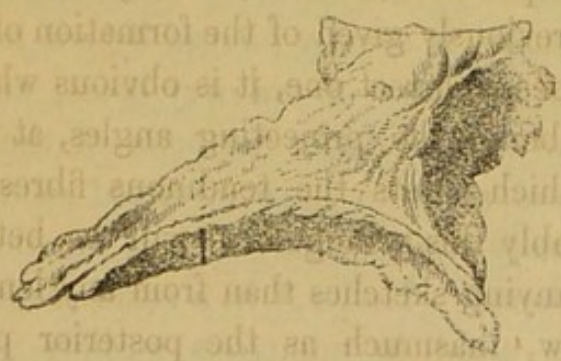
tholomew's Hospital, exhibiting vertical sections of the anterior aortic and pulmonary valves of the ox. Any doubt as to the nature of this disposition of parts in the human heart, is at once removed by an examination of the same parts on a larger scale. This arrangement appears of importance when viewed in connexion with the functions of the valves. Dr. Reid* describes the reflux as sustained in part by the festooned rings at the base of the valves, but in fact they are thinnest at this very part, corresponding to the central portion of the convexity of the valve; and if the description previously given of the formation of the tendinous festooned rings be a correct one, it is obvious why it is so—the thicker portions being the projecting angles, at the junction of two valves, to which points the tendinous fibres of the valves converge. Probably this arrangement will be better understood from the accompanying sketches than from any lengthened verbal description. Now, inasmuch as the posterior portion of the aortic orifice is continuous with the left auriculo-ventricular ring, no

* Cyclopædia of Anatomy and Physiology, art. "Heart."

muscular tissue of the ventricle existing in this part, the posterior aortic valve and a portion of the adjacent one have no support of this kind, and here, indeed, "the force of the reflux is (entirely) sustained by the stouter and more tendinous part of the arterial valve;"* but the muscular floor of the anterior aortic valve is especially broad, and is formed by the anterior extremity of the upper border of the septum of the ventricles; and it is the corresponding portion of the aorta which is especially dilated; the posterior wall descending nearly vertically. The contrast is well shown in an antero-posterior vertical section of the vessel. This arrangement obtains in all three pulmonary valves; but as the walls of the right ventricle are considerably thinner than those of the left, the muscular floor of these valves is much narrower than in the anterior aortic valve. All this is of course much more plainly seen in the hearts of the larger animals,—as the horse and ox; and here, where the muscular floor of the valves, more especially the anterior aortic, is of very considerable breadth, the tendinous tissue of the valve may be traced over the muscular surface to join the wall of the vessel.

In the larger ruminants, two considerable portions of bone are found partly surrounding the orifice of the aorta, and smaller irregular fragments are occasionally observed between the principal pieces. The larger portions also vary much in size and shape in different hearts, even of the same species. They are usually elongated and curved, and the larger bone thickest from above downwards, bearing some resemblance to one of the upper ribs. The chief bone (Fig. 6) of the ox, (from which the description is

Fig. 6.



* A. Retzius. Muller's Archiv: Mr. Paget's Reports, 1843, p. 14.

more immediately taken,) which exceeds the other considerably in size, embraces the whole of the right side, and the right half of the back part of the orifice of the aorta, while the little bone (Fig. 7), not generally found in the smaller ruminants, as the

Fig. 7.

sheep, its place being occupied by a portion of dense fibrous tissue, extends from the middle of the left side, round to the posterior part, where it more or less nearly joins the extremity of the larger bone. Thus, the lateral and posterior portions of the aortic orifice are surrounded by firm bony arches, meeting posteriorly in the centre. From the large bone a small process usually passes backwards for some distance into the muscular substance of the septum between the ventricles, and is gradually lost in the dense fibrous tissue found in this part surrounding the right border of the left auriculo-ventricular aperture; and from the convex surface of the smaller portion, a thin process of dense fibrous tissue is continued round the left margin of the auriculo-ventricular orifice. These heart-bones are intimately connected above with the middle coat of the aorta; on the inner surface with the base of the adjacent arterial valves; and posteriorly with the anterior mitral valve; while at the sides, to their external and inferior surfaces, the muscular fibres of the ventricle are attached. They may be seen and felt in the base of the pouches formed by the two posterior aortic valves, and no doubt greatly assist in sustaining the "force of the reflux." The larger bone, towards its posterior extremity, is usually pierced by one or two foramina. They possess the structure of ordinary bone; and they occupy the position of the two posterior festoons of the aortic valves. These curious bones seem to have attracted comparatively little attention. Generally, indeed, only one is mentioned, under the name of "heart-bone." Haller,* in a small section headed "Os Cordis," refers, as usual, to numerous authors who have men-

* Elementa Physiologiæ, liber iv., sect. xviii.

tioned it in their writings. Blumenbach* cursorily alludes to two, as existing in the stag, and the larger adult bisulca. In the human heart, in the situation corresponding to the position of these heart-bones, the tissue composing the festooned rings is thicker and denser than elsewhere, offering to the knife, in some cases, almost the resistance of bone. The processes of dense fibrous tissue found in the anterior portion of the border of the septum, &c., and extending round the right and left margins of the auriculo-ventricular orifice, have been already described. They are intimately connected with the thickened portion of the adjacent festoons.

The arterial valves have generally been described as consisting of a "duplicature of the lining membrane, with enclosed tendinous structure;" or, as "formed of tough, close-textured, fibrous tissue, with strong interwoven cords, and covered with epithelium." The arrangement of the principal tendinous bands, and the formation of the corpus Arantii, lunulæ, &c. have been accurately described. The bands of tendinous fibres are plainly seen spreading out into the substance of the valves. Their general direction is very obvious, even to the naked eye. Besides the principal bands, which have especially received attention, more delicate ones may be observed, arranged throughout the whole substance of the thicker portions of the valves, curving for the most part in the direction of either their free or attached margins, according as they are nearer the one or the other. At the juncture of two arterial valves, where they are continued up on the inner side of the vessel, many of these bands converge, and becoming intimately blended with the arterial coat, enter into the formation of the festooned tendinous rings. In the tendinous bands contained in the valves, all the characters of the white fibrous tissue are very beautifully shown. The delicate undulating bands, composed of the finest filaments, cannot, with ordinary care, be mistaken for any other structure. The fibres of elastic tissue have been detected in the corpus Arantii, (Purkinje, Raeuschel,) but there appears to be no record of their existence throughout the substance of the valves. In repeated examina-

* Comparative Anatomy, translated by W. Lawrence, p. 138.

tions of different portions of the arterial valves, elastic fibres have been constantly found. They exist most abundantly in the thicker portions of the valves, but even in the thinner portions (lunulæ) a few delicate, but well-marked elastic fibres may be generally seen, especially after the addition of acetic acid, which, of course, assists greatly in bringing them to view. The existence of muscular fibres in the arterial valves has been often affirmed. They are described by many of the older anatomists,—Lancisi,* Senac,† &c. Morgagni says that fleshy fibres are very visible in the valves of the pulmonary artery, but it is not so easy, he adds, to demonstrate them in the valves of the aorta. He represents them, however, in the valves of this vessel.‡ Cowper§ speaks of "carneous fibres variously interwoven." Winslow‖ declares that, "In examining these valves by the microscope, we find some fleshy fibres in the duplicature of the membranes of which they are composed." Haller¶ alludes to some eminent men who describe them as forming two muscles which contract and dilate the valves. He himself speaks very cautiously, and strongly doubts their existence. More recently, Dr. Monneret** has given an elaborate description of several bundles of organic muscular fibres, which he declares exist in the valves. He divides them into two sets, according to their direction and supposed action, elevators and depressors, and he continues—"These fibres, under a power of seven hundred diameters, had all the characters of the muscular fibres of organic life, being, namely, smooth and *cylindrical*." (?) Mr. Moore,†† after quoting some authorities in support of the opinion that muscular fibres exist in the valves, also figures two sets, which he describes as dilators and retractors. I have repeatedly sought for

* De Motu Cordis.

† Traité de la structure de Cœur (livre i.), where numerous authorities are mentioned who described the valves as muscular.

‡ Adversaria Anatomica omnia, tab. iv.

§ Myotomia Reformata.

‖ Exposition Anat. de la Structure du Corps Humain, p. 592.

¶ Elementa Physiologiæ, liber iv., sect. 10.

** In a paper "On the Structure and Physiology of the Valves of the Aorta and Pulmonary Artery."—The Lancet, Dec. 29, 1850.

†† In a paper in the Medical Gazette, March 8, 1850.

muscular fibres in the arterial valves, but have never yet succeeded in detecting any such structure; and, from the descriptions given by the above-mentioned observers of their arrangement and direction, it seems highly probable that the tendinous bands before described have been mistaken for muscular fibres.

If now we examine a similar section of an auriculo-ventricular valve, we shall obtain an important view of its construction. Figures 8 and 9 represent vertical sections through the centre of the large tricuspid and posterior mitral valves. The convexity

Fig. 8.

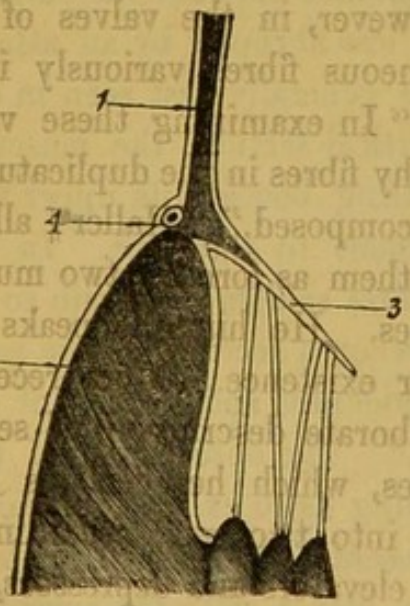
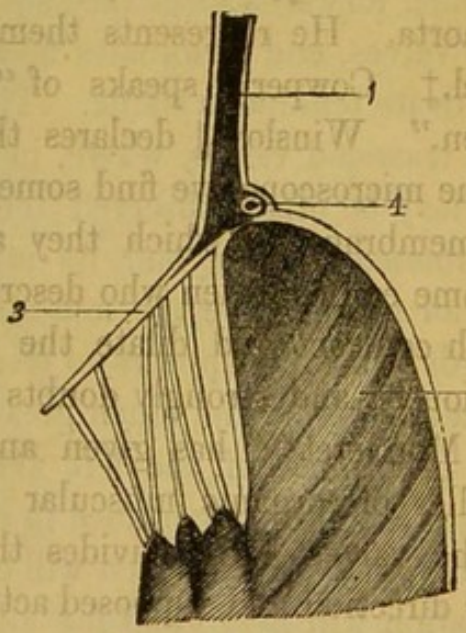


Fig. 9.



1. Section of auricle.
2. Section of ventricle.
3. Section of valve.
4. Section of coronary vessel.

of the upper border of the ventricle is now well seen (and this is much more marked on the left side, where the ventricular wall is so much thicker,) and sections of the coronary vessels are shown, occupying the groove in this manner formed. In commencing to trace the lining membrane of the auricle downwards, we find that at a point either opposite, or, as in the case of the posterior tricuspid valve, just above the border of the ventricle, it is continued on to the upper surface of the valve, which is usually described as "formed by a doubling of the lining membrane of the auricle and ventricle, containing within it numerous tendinous fibres." From the under surface of the valve the membrane may be traced on to the inner surface of the ventricle.

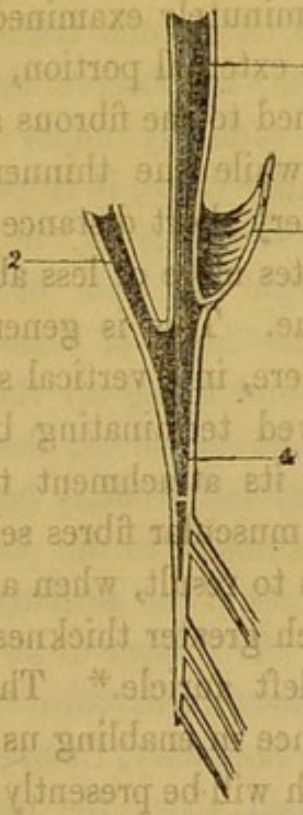
The section plainly shows that while the lining membrane of the auricle is continued on to the valve by a gentle curve, an acute angle is formed beneath, between the under surface of the valve and the inner wall of the ventricle. In tracing downwards the muscular wall of the auricle, we now at once observe, what was before noticed, that it is continued on to the inner surface of the ventricular border, and if minutely examined is seen to terminate by two attachments. The external portion, which is considerably the larger, is closely attached to the fibrous structure forming the auriculo-ventricular ring, while the thinner internal portion is continued forwards for a very short distance between the surfaces of the valves, and terminates more or less abruptly by an attachment to its tendinous tissue. This is generally best seen in one of the tricuspid valves, where, in a vertical section, the muscular fibres may be often observed terminating beneath its upper surface, immediately beyond its attachment to the ring. In the posterior mitral valve the muscular fibres seldom penetrate so far forwards; and this appears to result, when a section of the parts is examined, from the much greater thickness and density of the lining membrane of the left auricle.* The observance of this arrangement is of importance in enabling us to explain some contradictory statements which will be presently noticed. The above description will hold good for all the valves, with the exception of the anterior mitral, the construction of which may now be examined.

If we dissect down between the anterior wall of the left auricle and the posterior surface of the aorta, we shall find that the central fibres of the auricular wall are closely attached to the adjacent wall of the vessel. A little further dissection on either side will show that the muscular substance of the left ventricle is deficient between these parts. At the sides, indeed, it is found, but is gradually lost at some distance from the mesial line. Hence it

* The difference between the lining membranes of the two auricles is very marked,—so obvious indeed that it is generally easy to tell at a glance to which auricle a portion of the lining membrane given for inspection belongs. On the left side it is much thicker, tougher, and more opaque, not allowing the colour of the muscle beneath to be seen through it as on the right side.

has been already noticed that these two orifices (the aortic and left-auriculo-ventricular) are not separated, as the others are, by the intervention of muscular fibres, their boundaries being formed by other tissues. Fig. 10 represents a vertical section through

Fig. 10.



1. Section of aorta.
2. Section of anterior wall of left auricle.
3. Section of semilunar valve.
4. Section of anterior mitral valve.

the anterior mitral valve, near the centre, including the posterior wall of the aorta, and the anterior wall of the left auricle. If we trace downwards the lining membrane of the auricle, we find it directly continued on to the posterior surface of the valve; and in tracing upwards the membrane on the anterior surface of the valve, we find it continued over the tendinous festooned ring of the aorta on to the under surface of its valves, and into the space between them. The anterior mitral, it may be observed, lies beneath a portion of the two posterior arterial valves, their junction being somewhat to the right of the centre of the mitral valve; and in order to show the relations of the different parts more clearly, the sketch represents a section through that part of the mitral valve corresponding to the centre of one of the aortic

valves. If now we trace the muscular wall of the auricle downwards, it is observed terminating by two distinct insertions. The anterior (the larger) division of fibres is attached to the posterior surface of the aorta, opposite to and below the festooned ring; while the posterior portion is continued directly downwards for a short distance into the valve, and terminates more or less definitely by an attachment to its fibrous tissue. In tracing downwards the wall of the aorta, we observe that, descending nearly vertically, and becoming suddenly much thinner opposite the upper border of the semilunar valve, it is continued down to the festooned ring, (shown in section;) or, in other words, that it here becomes blended with the base of the semilunar valve. Below this, we trace a dense layer of fibrous tissue, before described as existing below, and filling up the spaces between the attached bases of the semilunar valves, descending for some distance into the mitral valve, immediately behind its anterior surface. It is by a close attachment to the posterior surface of this layer that the muscular fibres of the auricular wall, which descend into the valve, terminate. This layer of fibrous tissue may, however, be generally traced downwards into the valve farther than the muscular fibres. The boundary, then, between the aortic and auricular apertures is formed above the mitral valve by the posterior wall of the aorta, terminating at its junction with the bases of the semilunar valves, and immediately below the posterior surface of which is attached the greater portion of the muscular fibres forming the anterior wall of the left auricle. The extremities of the two bones which in ruminants replace a portion of the lateral and posterior divisions of the festooned ring, nearly meeting in the centre behind, give additional support to the structures entering into the formation of the mitral valve.

The tissues composing the auriculo-ventricular valves have frequently been examined, and very contradictory statements have been advanced as the result of observation. That the greater portion of the valves is composed of white fibrous (tendinous) tissue, is generally admitted, and this appears derived in great part from the chordæ tendineæ, which spread out at their insertion into the substance of the valve. Kürschner's now well-known

description of the arrangement of the three orders of tendinous cords in the valves must be allowed to be very artificial. It is best seen in the anterior mitral, and in the largest tricuspid valve. An observation long since made by Cruveilhier has generally been overlooked. He says,—"the chordæ tendineæ of the heart terminate in the auriculo-ventricular zones, either directly, or indirectly through the medium of the valves." * There can be no doubt that a considerable portion of tendinous fibres passes from the insertion of the cords to the zones, and many of the smaller cords themselves pass up directly into the angle formed between the under surface of the valve and the inner surface of the ventricle, and at once enter into the formation of the fibrous zones. These cords are generally short, and many of them spring from the wall of the ventricle behind the valve. Therefore, it results that these zones are densest and most strongly marked in those portions corresponding to the attached borders of the valves, and gradually become less distinct towards the intervals between them. It has been generally noticed that the left zone is altogether denser and stronger than the right. Thus it is, as has been already suggested, that the greater portion of the auriculo-ventricular zones is more properly to be considered in relation with the valves.

The most superficial glance at any one of these valves will show how unequally the tendinous tissue is distributed throughout their substance, and that it exists in great abundance along their attached margins, which are thus much thickened and condensed. The upper attached portion of the anterior mitral valve also receives its fibrous tissue from another source—viz. from that layer already described as descending a short distance into its substance from the inferior border of the arterial wall. It has also been mentioned that in this layer of fibrous tissue a moderate quantity of yellow elastic tissue is blended, and these fibres are therefore found in the upper portion of the mitral valve. Is it confined to this situation? and does it exist in the other valves? The presence of elastic tissue in any of the valves does not appear

* Anatomie Descriptive, par J. Cruveilhier, vol. iii. p. 24.

to have been noticed. It has been described as existing abundantly beneath the lining membrane of the auricles, but is said to be absent beneath the lining membrane of the ventricles, and in the valves. In numerous examinations it has been found very scantily scattered beneath the lining membrane of the ventricles, except, perhaps, over the columnæ carneæ, where the membrane is especially thin; but in the auriculo-ventricular valves it may be found more abundantly, especially in the thickened portions, and near their attached borders, beneath the under as well as the upper surface. It exists more plentifully in the anterior mitral valve, especially towards the upper part. It may also be detected in the chordæ tendineæ. It is, however, more abundantly found in the arterial than in the auriculo-ventricular valves.

Lastly, are muscular fibres contained in the auriculo-ventricular valves? Their presence has been alternately affirmed and denied. Dr. Reid* asserts that they do not exist in the valves of the human heart, and says, "in making examinations of this kind we must be exceedingly careful not to mistake the tendinous fibres when they are tinged with blood for muscular fibres; for under these circumstances," he continues, "they certainly at all times assume the appearance of muscular fibres." If the microscope be employed, this mistake is not likely to happen. Lancisi† and Senac‡ long since described muscular fibres in the segments of the auriculo-ventricular valves, and Kürschner has more recently confirmed the observation. He says, "The auriculo-ventricular valves are composed (besides their proper tissue and the endocardium) of the continuation of the tendinous cords, which usually spread out like palm-leaves, and are interwoven; and of muscular fibres, of which a certain number may be traced (especially after several days' soaking in cold water) passing from the adjacent wall of the auricle into the interior of each division of the valves, and connecting themselves with the ends of the tendons of the

* Cyclopædia of Anatomy and Physiology, vol. ii. p. 589.

† De Motu Cordis.

‡ Traité de la Structure du Cœur, livre i. p. 76.

second order in the central portion of the valve."* The existence of muscular fibres in the valves is not generally admitted. Probably these contradictory statements may be in some measure reconciled by a consideration of the arrangement already described, and by a reference to the sketches. The internal fibres which have been mentioned, descending from the auricular walls into the valves just beyond their attached margins, may be traced to a greater distance into their substance in some cases than in others. They generally terminate by a tolerably well-defined margin; but this varies. They usually descend for a greater distance between the layers of the anterior mitral valve, immediately in front of its auricular surface; but even here they are seldom found stretching far into the valve—not terminating, however, so abruptly. Although extending below the attached bases of the semilunar valves, I have never succeeded in tracing them so far as the central portion of the valve, as described by Kürschner; and it is difficult to conceive what advantage is gained by previously soaking the valves for several days in cold water, if the microscope be employed; and without this instrument, observation will be of little value, for we are very likely to fall into the error before alluded to by Dr. Reid. Therefore, if a portion of the attached border of a valve, immediately below its upper surface, be examined, muscular fibres in abundance will generally be detected; whereas, if sought for in any other portion of the valve far from its attached border, according to the foregoing observations, they will not be found.

It may be well, in conclusion, to enumerate the principal points which have been discussed in the preceding pages. An attempt has been made to explain,—

The real connexion that exists between the auricles and ventricles, and their relation to the fibrous rings; the formation of the grooves in which the coronary vessels lie, &c.

The nature and mode of formation of the "tendinous festooned rings" surrounding the arterial orifices.

The exact connexion existing between the semilunar valves and

* Mr. Paget's Reports for 1843, p. 1.

the upper border of the ventricles, upon which a portion of the valves rests, and by which they are supported.

The different tissues entering into the formation of the arterial and auriculo-ventricular valves; the connexion between the muscular tissue of the auricles, and the auriculo-ventricular valves.

The relation of the aortic to the left auriculo-ventricular orifice, and the construction of the anterior mitral valve.

This paper was read before the Royal Society in December, 1851. While these pages were passing through the press, Mr. Paget shewed me a paper in the "Nederlandsch Lancet" for March and April, 1852, by Professor F. C. Donders, entitled "Onderzoekingen betrekkelijh den bouw van het menchelijke hart." In his description of the anatomy of the valves, Professor Donders, for the most part, confirms my observations. Indeed, as he has not seen my paper, some of his illustrations coincide remarkably with mine. Professor Donders appears to have investigated very minutely the structure of the valves. While he describes the filaments of yellow elastic tissue as most abundant on the upper surface of the auriculo-ventricular valves, he states that it is most plentifully found on the under surface of the arterial valves. Professor Donders also describes and figures stellate corpuscles which he has discovered in the festooned tendinous rings. They appear very similar to those irregular stellate cells or nuclei which have been lately observed in many of the fibrous as well as in some of the cartilaginous tissues; also closely resembling those irregularly branching "stellate or spicate" corpuscles which are found so abundantly in many forms of cartilaginous tumours. These, and many other interesting points, are minutely described in the paper.

Wilson and Ogilvy, 57, Skinner Street, Snowhill, London.