

VI. *On the Development of the Great Anterior Veins in Man and Mammalia; including an Account of certain remnants of Fœtal Structure found in the Adult, a Comparative View of these Great Veins in the different Mammalia, and an Analysis of their occasional peculiarities in the Human Subject.* By JOHN MARSHALL, F.R.C.S., lute Demonstrator of Anatomy in University College, London; Assistant Surgeon to the University College Hospital. Communicated by Professor SHARPEY, F.R.S.

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THE principal object of the present paper is to state the result of observations on the metamorphosis of certain of the great veins in Man and Mammalia, and on the relation between the primitive and final condition of these vessels, both when they pass through their changes in the usual order, and in cases of deviation from it.

It is well known that in the mammalian embryo the great veins entering the heart from the upper or anterior part of the body are originally symmetrical on the two sides; and that in Man, the Quadrumana and most of the higher orders of quadrupeds, the venous trunk of the left side undergoes occlusion; whilst in other Mammalia that vessel continues, and constitutes, in the adult state, a left vena cava anterior, which passes down in front of the left lung, and then along the back of the heart in the auriculo-ventricular groove to terminate in the right auricle. Certain points of analogy between these different conditions are suggested by a careful examination of the great veins in adult hearts, more especially of what is usually regarded in the human subject as the dilated termination of the great coronary vein in the right auricle. This portion of the vessel (Plate I. fig. 1, *s*), which has muscular parietes, is, on account of its width, usually named the coronary sinus. Its length may be considered as defined by a valve (*x*) placed about an inch or more from its opening into the right auricle. This valve, which was known to VIEUSSENS\*, has been again recently pointed out by Dr. JOHN REID†, and is described by him as generally existing and formed of one or two segments. In all the examinations which I have made I have found it present, and always consisting of two segments; a larger one placed on the side of the auriculo-ventricular furrow, and a smaller one situated on the free side of the vein, and therefore liable to be divided in slitting up

\* *Traité de la Structure, &c. du Cœur.* Toulouse, 1715, p. 56.

† *Cyc. Anat. and Phys., Art. Heart*, p. 597.

that vessel (see Plate I.). Into the extremity of the coronary sinus, as thus defined, the great coronary vein (*g*) may be said to open, its entrance being guarded by the valve alluded to; and along the lower border of the sinus there enter three or four venous branches (*p, p, p*), which ascend from the back of the ventricles, one of them generally forming the middle cardiac vein (*m*); the mouths of these branches are also almost invariably provided with fine valves consisting of one or two segments, but beyond the coronary sinus and the larger valve first noticed, no more valves are met with either in the trunk of the principal cardiac or coronary vein, or in any of its tributary branches.

In the hearts of the Monkey, Cat and Dog, a precisely similar arrangement is observed.

In those animals which possess a left vena cava superior, the great cardiac or coronary vein ends in that additional venous trunk, as seen, for example, in the Marsupialia, many of the Rodentia, and in the Elephant. Moreover in certain Ruminant and other animals, as for example the Sheep (Plate I. fig. 2), in which a large left azygos vein exists, arching over the root of the left lung and thence pursuing the same course to the right auricle as the left vena cava superior in the cases already alluded to, the coronary vein (*g*) opens into this azygos venous trunk (*ss'*). In both these two conditions, as I have observed in the Rabbit, Hedgehog, Ox, Sheep and Pig, the lower part of the large left venous trunk is always dilated and muscular, and at the opening of the coronary vein into it, there is found a large valve composed in some cases of one segment (*x*), and in others of two. A series of small veins (*pmp*), ascending from the back of the heart, join it at intervals between the valved entrance of the coronary vein and the opening of the venous trunk itself into the right auricle; and, lastly, the mouths of these ascending cardiac veins are for the most part regularly provided with valves, whilst, on the contrary, no valves exist along the continuation upwards of the large venous trunk, at least in the neighbourhood of the heart; nor are valves met with, as a constant condition, in any other part of the cardiac veins themselves.

On comparing, in Man and Animals, the arrangement of these vessels and the disposition of their valves, I was led to conjecture that *the dilated and somewhat muscular portion of the coronary vein, usually named the coronary sinus* (Plate I. fig. 1, *s*), together with its large and important opening (*t*) into the right auricle, as seen in Man and such of the higher Mammalia as have no left vena cava superior or left azygos vein, *was strictly analogous to the expanded lower portion* (fig. 2, *s'*) and auricular orifice (*t*) *of those additional left venous trunks*, as found in other quadrupeds; and, in fact, that it was *the persistent lower part of the left anterior primitive venous trunk*.

On this supposition, the coronary vein *proper*, in Man and the higher Mammalia, might be said to end in the so-called coronary sinus, at the valved orifice above described; and thus its mode of termination, instead of varying in different cases, would be similar throughout the entire mammalian series,—the vessel in no case reaching

the right auricle directly, but always pouring its blood, like the posterior cardiac veins generally, into a larger venous trunk.

The analogy thus indicated between the coronary sinus on the one hand, and the lower portion of the left vena cava superior or left vena azygos on the other, is apparent, not only in their likeness as to shape and structure and the disposition of their branches and valves, but also in the similarity of their situation, direction and connections with the heart, and in the resemblance, not altogether overlooked by anatomists, of their respective openings into the right auricle.

According to RATHKE, however, whose authority is generally followed, the left anterior primitive venous trunk in the human subject closes and entirely disappears in the progress of development, from the root of the neck down to the heart. But if, on the contrary, the coronary sinus, as found in the adult condition, in Man and some of the higher Mammalia, be, as is above suggested, the *analogue* of, or, to express the fact in another form, be the *lower pervious portion* of the left primitive vein, might it not possibly happen that, even on the fully-formed heart, some remnant of its *upper occluded portion* should still exist, above the valved entrance of the coronary vein into the coronary sinus?

Searching, accordingly, in the adult human heart, I have found, in upwards of twenty different instances, certain parts or structures (Plate I. fig. 1, *o*, *l*, *v*) always clearly distinguishable, though varying in distinctness, which, from their position and general character, are undoubted remains of the upper portion of the left primitive venous trunk.

Analogous remnants of the left primitive vein are also to be seen, in all those Mammalia in which—as in the Dog, the Cat and the Monkey—the same amount of occlusion of that vessel occurs as in the human subject; and a comparative examination of the arrangement of the veins in different animals, of the various instances of deviation from the ordinary condition in Man\*, and of the metamorphosis of these vessels in human and other embryos, has sufficed to establish, beyond a doubt, the identity of the parts under consideration.

The results of the entire investigation, together with due reference to the labours of others, may be conveniently presented under the following heads:—

1. Development of the great anterior veins.
2. Comparative view of the adult condition of these veins in Man and Mammalia.
3. Analysis of their varieties in the human subject.

\* In the thirteenth observation out of twenty-four, I fortunately met with an example of double vena cava superior in the adult, a rare and interesting variety in relation to the present subject. Since then I have had presented to me a second example, occurring in a child between four and five years old. I may take the present opportunity of thanking Dr. SHARPEY, Mr. STREETER and Mr. W. BENNETT for aid in procuring materials for this investigation.

## I. DEVELOPMENT OF THE GREAT ANTERIOR VEINS.

It has been shown by RATHKE\*, to whom we are chiefly indebted for our knowledge of the development of the veins, that in Man and Mammalia, as in the Vertebrata generally, the blood of nearly all parts of the embryo is returned to the heart by two pairs of venous trunks, viz. an *anterior* and a *posterior* pair, placed symmetrically in the lateral halves of the body. Besides these, however, there is a median inferior venous trunk, which forms in succession the termination of the omphalomesenteric and umbilical veins, and finally becomes the *vena cava inferior*.

Of the four lateral veins, the anterior pair, formed by branches from the head and neck, constitute the *jugular veins*. The posterior pair, which return the blood from the Wolffian bodies and the hinder part of the embryo, are called the *cardinal veins*. The cardinal and the jugular vein of each side join to form a short wide vessel, named the *canal of CUVIER*; and again, the two canals of CUVIER (so named from their resemblance to the ductus Cuvieri in fishes) running downwards and forwards at the sides of the œsophagus, unite in front of that tube into a common trunk, which immediately enters the yet undivided auricular portion of the heart. In the subsequent enlargement of the yet single auricle, this common trunk comes, as it were, to form part of that cavity, into which accordingly the two canals of CUVIER henceforth open separately, and thus represent two superior venæ cavæ, one on each side.

When the Wolffian bodies disappear, the cardinal veins diminish in size, returning the blood from the hinder limbs and trunk of the embryo only. In the mean time the intercostal veins are formed and united together by vertical anastomoses on each side, so as to form the azygos and hemiazygos veins. Finally, in Man, the left cardinal vein becomes, according to RATHKE, *entirely obliterated*, whilst the upper portion of the vein of the right side is probably concerned in the formation of the termination of the azygos vein.

In the meantime a transverse connecting branch is developed across the lower part of the neck, between the two jugular veins. This transverse branch is rapidly enlarged, and then, in the human embryo, and also in those animals which have no permanent venous trunk on the left side, that portion of the original left jugular trunk which is situated lower down than the transverse branch, or nearer to the heart, and also the left canal of CUVIER which is continuous with it, shrink and disappear; the enlarging transverse branch across the neck forms the left innominate vein; and the lower part of the right jugular with its canal of CUVIER, receiving the remains of the right cardinal vein, now the terminal part of the vena azygos, constitutes the vena cava superior as ordinarily met with: thus the metamorphosis is complete.

In the Sheep, however, it was observed by RATHKE, that the upper part of the left

\* RATHKE, "Ueber die früheste Form und die Entwicklung des Venensystemes beim Schafe" (MECKEL'S Archiv für. Anat. und Phys. 1830, p. 63); also, more particularly, "Ueber den Bau und die Entwicklung des Venensystems der Wirbelthiere"—(Dritter Bericht, über das Naturwissenschaftliche Seminar bei der Universität zu Königsberg. Königsberg, 1838).

cardinal vein and the left canal of CUVIER remain open to form the left azygos vein present in that animal; whilst that part of the left primitive venous trunk which is situated between the canal of CUVIER and the junction of the left subclavian and jugular veins, disappears, and only a subordinate twig is subsequently found in its place, which ends in a small left superior intercostal vein.

Lastly, in those animals which in the adult condition have a right and left superior vena cava, the left primitive jugular vein, together with the corresponding canal of CUVIER, remains pervious throughout life. This knowledge of the common type of formation of the veins in the Vertebrata, and of their metamorphosis in certain species by partial occlusion, suggested to RATHKE the explanation of the occasional occurrence of double vena cava superior in the human subject as the result of an arrest of development. Nevertheless, the details of this metamorphosis have not been fully indicated, nor, as far as I am aware, have any persistent remnants of the foetal structure been recognized in the adult. By RATHKE himself the left primitive vein is said, in Man, to *diminish and entirely disappear from opposite the left end of the transverse vein of the neck, down to the heart*; but this seems to have been an inference from the known adult condition, and I do not know that either he or others have given any description or delineation of the development of these veins, as actually traced in the human embryo.

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The metamorphosis of the primitive lateral and symmetrical venous trunks in the higher Mammalia and in Man may be said to consist of *two fundamental changes*, viz. *a.* the formation of the cross branch or communication in the neck, and, *b.* the occlusion of a greater or less portion of the left primitive venous trunk. Besides this, however, there are, during embryonic life, *c.* certain concurrent and subsequent alterations in the size, position and direction of the venous trunks which finally remain pervious. Lastly, *d.* there are the changes which take place after birth.

### *Development in the Sheep.*

#### *a. Formation of the Transverse Communication in the Neck.*

In embryos measuring  $\frac{1\frac{1}{2}}{20}$ ths of an inch, well-preserved in spirit, and in which the blood was hardened in the veins, no appearance of a cross branch was discernible. The earliest satisfactory indications of its commencement were met with in embryos from  $\frac{1\frac{3}{20}}{20}$ ths to  $\frac{1\frac{5}{20}}{20}$ ths of an inch in length. In these (Plate II. figs. 1, 2, 3), two little spur-shaped points, filled with hardened blood, projected towards each other from the inner borders of the jugular trunks (*a a'*) immediately above the commencing pericardium, on a level with the subdivision of the ascending aorta. In some cases, no intermediate portion of vein between these points could be detected; but in others the connection was evidently completed by a material, more opaque than that around, which could be often raised as an indistinct narrow cord, containing however no

hardened blood (fig. 5, *d*). Even in embryos as long as  $\frac{1}{20}$ ths of an inch (fig. 4), no red line could be traced quite across the neck, although the lateral primitive veins were turgid with blood, and presented two conical projections at the situation of the cross branch.

This cross branch is supposed to be formed by the enlargement of a previously developed vessel of almost capillary dimensions, perhaps one of several such vessels passing across the neck; but it is possible that it might be formed in the same way as the other great vessels. The appearances above described would suggest the idea that this transverse branch was formed by the budding out and subsequent junction of two opposite points of the older veins, but this appearance is probably owing merely to the vessel being smaller and empty of blood in the middle of its course, or to its being accidentally broken at that point; but still it would seem that the extremities of the new transverse vein in connection with the older vessels are at first always enlarged more than the intermediate portion. In recent embryos of the Guinea Pig, measuring about half an inch in length, I have twice recognized the transverse branch as a very *minute continuous* vessel, passing quite across the neck, between the two jugular veins, just above the pericardium. In one very early embryo ( $\frac{6}{20}$ ths of an inch long), a small vessel, evidently a vein, traversed the neck higher up, supported by the branchial arch which was being transformed into the lower jaw; the lower cross branch was not yet formed in this case.

During the widening of the cross branch, the two jugular trunks (*aa'*) at that point gradually approach each other,—the distance between them, absolutely as well as relatively, decreasing (compare figs. 2 and 6, representing embryos of  $\frac{1}{20}$ ths and  $\frac{1}{20}$ ths of an inch in length). Instead of descending parallel with each other, these veins now incline to the middle line of the neck, opposite the cross branch, and assisted by the shortening and widening out of that vessel, they appear at length to coalesce, almost by lateral adaptation, before any diminution of the left primitive vein has begun to take place (fig. 7, embryo 1 inch  $\frac{2}{20}$ ths long).

In later embryos (fig. 8, 1 inch and  $\frac{3}{20}$ ths long; fig. 10,  $1\frac{1}{2}$  inch long), in which the neck is already becoming elongated, by the time that the occlusion of the left primitive vein is accomplished, the two jugular veins, having received the large superficial veins of the neck and those from the anterior limbs, are so closely applied to each other, and their connecting branch is become so entirely absorbed into them, that they join together at a very acute angle; or rather, the vein of the left side, now the left innominate vein, runs continuously into the lower part of the right primitive vein, or superior vena cava, whilst the right innominate vein appears to fall into this large continuous trunk at an acute angle.

At still later periods, when the vertebral column projects prominently forward at the lower end of the slender neck, immediately above the narrow aperture of the thorax, this obliquity of the junction between the innominate veins is as marked as in the adult animal.

b. *Occlusion of a portion of the Left Primitive Vein.*

Before the commencement of this stage of the metamorphosis, the jugular trunks are closely approximated and open freely into each other by means of the wide and very short communicating branch (fig. 7, *d*). Previously to this change also, that portion of both primitive jugulars which is situated below the cross branch, becomes elongated in accordance with the growth of the thorax, and now, inclining outwards, descends through a much longer course upon the pericardium, beneath the pleura, to join the cardinal vein of its own side and end in the corresponding canal of CUVIER. It is just this portion of the left primitive jugular vein, viz. from the transverse branch in the neck to the commencement of the left canal of CUVIER, which becomes closed in the Sheep. In embryos measuring 1 inch and 1 line (fig. 7), the vessel (*a'*) has either not begun, or is only just beginning to shrink; but so rapidly does the process take place, that in others scarcely 1 line longer (fig. 8), the vessel is already closed, and now appears as a semitransparent cord (*o*) extending from the point of junction of the primitive jugular trunks in the neck, to the arch formed by the left cardinal vein (*b'*) and left canal of CUVIER (*c'*). This cord is finer at its lower end; it lies at first in front of the aorta, and then passes down close to the pericardium, on the left side of the ductus arteriosus; it is in contact, below, with the left pleura; the par vagum descends behind it, and it is crossed by the phrenic nerve. Close behind the upper end of this cord, but not actually connected with it, a considerable vein, formed by the left vertebral and a large perforating intercostal from the back, joins the under side of the left innominate vein.

In later embryos the above-mentioned cord becomes less and less distinct; in an embryo measuring  $1\frac{1}{2}$  inch long (fig. 10) it cannot be continuously traced, and in a foetal sheep, 4 inches in length (from the vertex to the tail), it is not perceptible. In its place, however, there is found a long ridge or elevation of the pericardium, containing fibrous tissue, which may be followed from below upwards, close to the left side of the large ductus arteriosus, in a direction towards the middle of the root of the neck. Above the pericardial sac, the traces of it are almost entirely lost.

c. *Concurrent and subsequent Changes in the Pervious Vessels.*

In *size*. As the left primitive vein is undergoing occlusion, the lower part of the right jugular vein (figs. 8, 10, *a*), and the right canal of CUVIER, simply enlarge, as RATHKE states, to form the superior vena cava. The adjoining part of the right cardinal vein, having first shrunk in consequence of the wasting of the Wolffian body, remains for a considerable time as a right azygos vein, equaling in size the left azygos; but about the middle of foetal life it is smaller than the vein on the left side, and afterwards, its connection with the right intercostal veins being gradually cut off, it slowly diminishes until it exists only as a very small vessel, or sometimes wholly disappears. The left cardinal vein (*b'*), on the contrary, forms, after the disappearance of the corresponding Wolffian body, a left vena azygos, which, though for

a time of the same size as the right azygos, afterwards surpasses it, in consequence of receiving the lower right intercostal veins, in addition to almost all those of its own side. The left canal of CUVIER (*c'*), reduced greatly in width after the occlusion of the primitive jugular vein, constitutes the intrapericardial part of the left azygos vein, and with the rest of that vessel forms a venous arch, which turns over the root of the left lung, and is connected above with the cord-like vestige of the occluded vein (*o*).

In *position* and *direction*. The cardinal veins, in order to unite with the jugular veins in the corresponding canals of CUVIER, bend forwards above the commencing lungs (figs. 1 and 2,—4, 4'), from which they are for a time separated by the upper end of the Wolffian bodies (5, 5'). The rudimentary right lung being, almost from the commencement, larger and somewhat higher up in the thorax than the left, the right cardinal vein (*b*), even at a very early period (see figs. 2 and 9), reaches higher than the vein of the left side (*b'*); a peculiarity in position which subsequently increases, so that in a foetus of 4 inches in length the arch of the right azygos rises three lines higher up in the thorax than that of the left vein.

The cardinal veins, like the jugulars, are altogether outside the pericardium; but as soon as that sac is formed, the canals of CUVIER are found almost entirely within it. At first (figs. 1, 2, 3, *c*, *c'*) these canals pass horizontally forwards and inwards to the back of the auricular portion of the heart, into which they open on the same level, one on either side, in front of the inferior cava; but as the lungs enlarge and occupy more of the thoracic cavity, the Cuvierian canals have to descend more and more obliquely in front of the roots of those organs to reach the heart (figs. 7 to 10). In accordance with the higher position of the root of the right lung, this change in direction is more marked in the right canal of CUVIER, or future vena cava superior.

The heart itself, in the progress of growth, becomes slightly twisted, especially at its base or auricular part, its right border being turned somewhat upwards, supposing the thorax to be placed vertically (fig. 9, embryo 1 inch and 2 lines long; the parts being seen from behind). Hence the enlarged right canal of CUVIER (*c*) or upper vena cava reaches the future right auricle sooner and more directly than the smaller left canal (*c'*) or left azygos venous trunk; the former having a comparatively short and almost vertical course, whilst the latter, after having descended in front of the root of the left lung, has to turn beneath the base of the heart to gain its destined end in the right auricle. At the same time the position of the openings of the metamorphosed canals of CUVIER in the future right auricle undergo a change; for instead of both of them being placed, as at first, on the same level, one on each side of the inferior cava, the orifice of the right canal or upper cava opens widely into the highest part of the auricle, nearly in a line with the lower cava (*e*), whilst the left canal or left azygos ends at the lower and back part of the auricle close to the commencing septum. The serous layer of the pericardium is at first equally reflected over both the Cuvierian canals, but in time, whilst it covers only a smaller and smaller part of the anterior surface of the right canal, or upper cava, it forms a more and more



distinct *fold* or duplicature (fig. 10 *c'*), in which the left canal or left azygos trunk is lodged as it passes down in front of the left pulmonary vessels to reach the side of the left auricle immediately behind the appendix. Beyond that point, the vein, as it lies on the back of the left auricle, and runs along the auriculo-ventricular groove to reach the right auricle, is also covered by the serous layer of the pericardium. In the heart of a fœtus, 4 inches in length, several small veins from the substance of the left ventricle may be seen ending in the lower part of the left azygos trunk; and, amongst them, one, which joins it at an acute angle, is the future coronary vein.

#### d. *Changes at Birth.*

When, after birth, the short and wide ductus arteriosus shrinks, the long ridge of the pericardium with its contained fibrous tissue, already described as resting upon that vessel in the position of the occluded left vein, becomes closely applied to the left side of the aortic arch, and may be traced in the direction of a line drawn from the point of junction of the innominate veins at the root of the neck, down to the highest point of the arch of the left azygos vein.

Within the pericardium, the trunk of the left azygos occupies its proper *fold* of the serous membrane, and receives, shortly before its termination in the right auricle (as seen in Plate I. fig. 2), the coronary vein of the heart (*g*) and two posterior cardiac branches (*p, m*), besides a third smaller one (*p*), which might almost be said to end at once in the right auricle. The mouth (*t*) of this left azygos venous trunk is situated to the left of the orifice of the inferior cava (*e*), close to the interauricular septum, and below and behind the fossa ovalis, like that of the left superior cava in the lower Mammalia and in Birds. It has no Thebesian valve, which is represented, in the Sheep, merely by a slight ridge of the auricular parietes.

At the entrance of the coronary vein into the left azygos, there is, however, a large distinct valve (*x*), consisting of one strong segment. The two cardiac veins succeeding it are each guarded by finer valves of two segments, and the third vein generally by a single segment. Along the course of the coronary vein, there are from one to four other valves, consisting usually of one segment, but sometimes of two.

Lastly, the right azygos is now a much less important vein than that of the left side; it reaches from 3 to 5 inches higher in the chest, and is so small as to have been said by some anatomists, including RATHKE, to be always wanting. Occasionally, (once in five observations) it was found to be so trivial a vessel, that it was difficult to distinguish it as the actual persistent representative of the right cardinal vein.

#### *Development in Man.*

##### a. *Formation of the Transverse Branch in the Neck.*

No opportunity has offered itself of observing the time and mode of origin of the transverse branch in the human embryo, though it is probably originally formed in the same way as in the Sheep and Guinea Pig. In an embryo of  $\frac{1}{20}$ ths of an inch in

length (Plate III. figs. 1, 2), the cross branch (*d*) was already formed. Owing to the width of the human thorax, the jugular veins do not approach each other closely at the root of the neck, as in the Sheep; the cross branch continues of a much greater length, and, at first horizontal in its direction, only assumes after a considerable time, the somewhat oblique position which it permanently holds as the left innominate vein. RATHKE describes it as formed opposite the point of junction of the jugular and subclavian veins; but in the embryos dissected by myself, it is a little *lower down* than that point and immediately above the commencing pericardium.

*b. Occlusion of part of the Left Primitive Veins.*

It is not until after the transverse connecting branch is already nearly as large as either jugular vein, that the venous channels destined to be occluded begin to shrink. Previously to the commencement of this stage of the metamorphosis, the cardinal veins (figs. 1, 2, *b*, *b'*) have much diminished in size owing to the wasting of the Wolfian bodies (5); but the two halves of the venous system are still quite symmetrical, except that the arch of the right cardinal vein is higher up than the left, in accordance with the greater size and relative altitude of the corresponding lung, as already pointed out in the Sheep. From opposite the cross branch, the two jugular veins descend behind the auricular appendices outside the pericardium, to become continuous with the canals of CUVIER (*c*, *c'*), which, having received the cardinal veins, immediately enter the pericardium, and bend inwards beneath the auricular portion of the heart, into which they open, one on each side of and somewhat before the inferior cava.

In addition to a part of the left primitive jugular vein, lying outside the pericardium below the cross branch in the neck, it will be found that in the human subject, in which there is no left azygos as in the Sheep, the left cardinal vein shrinks into an insignificant branch, and entirely disappears as a distinct trunk; whilst the greater part of the left canal of CUVIER, placed within the pericardium, is also closed; its last part, however, situated on the back of the left auricle, remaining permanently open. This pervious portion of the Cuvierian canal eventually forms the coronary sinus.

The first step towards this occlusion consists in a gradual shrinking of the left primitive venous channel from the left end of the cross branch down to the back of the heart, as shown in an embryo of 1 inch and  $\frac{3}{20}$ ths in length (Plate III. fig. 3). The upper portion of the vein lies upon the aorta and ductus arteriosus, beneath the left pleura; whilst the lower portion, within the pericardium, crosses in front of the vessels of the left lung, lodged in a *duplicature* of the serous membrane, reminding one of the *fold* in which the left azygos vein is contained in the adult Sheep. The lower end of the vessel, placed on the back of the left auricle, is more dilated than the rest. In a more advanced embryo, 1 inch and  $\frac{11}{20}$ ths long, the closure was complete, and had probably been accomplished a considerable time (fig. 4). The place of the primitive vein is now seen to be occupied by a *fine cord* (*c''*), which may be followed *from the under*

*side of the left innominate vein down to the back of the auricle.* This cord is covered by the pleura, and crossed by the left phrenic nerve; it descends in front of the par vagum, upon the side of the aorta and ductus arteriosus to the left pulmonary artery, opposite to which it penetrates the pericardium. Within this sac it crosses the small interval between the left pulmonary artery and veins, enclosed in a minute *fold* of the serous membrane; and then, becoming applied to the back of the left auricle, expands into a small *conical pouch* (*c'*), which is narrow and pointed above, but wider below, where it opens into the right part of the yet undivided auricular cavity. No left superior intercostal vein could be found in this embryo.

In no other fœtus examined did the occlusion of the primitive left jugular vein extend quite up to the cross branch or left innominate vein; for there always remained a pervious but shrunken portion of the primitive vessel, which, as will immediately be shown, forms the *trunk* of the left superior intercostal vein. This fact is illustrated in fig. 5, *i*. In a somewhat later embryo (fig. 6), the cord of the occluded vein may be traced distinctly from the trunk of the left superior intercostal vein (*i*, which is here larger than usual), passing down through the fibrous layer of the pericardium, and entering its now narrow fold of the serous membrane (*c''*). Still later (Plate IV. fig. 9), the traces of a continuous cord above the pericardium are difficult to follow, and at the full period of fœtal life it is generally impossible to find in that situation more than a few fine vertical fibrous bands lying close beneath the pleura. The *little fold* of the pericardium, so often alluded to, soon after the closure of its contained vessel, sinks, as it were, into the interval between the left pulmonary artery and veins (Plate III. figs. 5, 6, *c''*), where it is found in all future stages, and increases in size with the other parts (Plate IV. fig. 9, *v*). Below the fold, the remnant of the closed vein descends upon the left auricle, and may be traced for a time, as a slight ridge, but afterwards, when the auricle enlarges, as an *opaque line or streak*, passing close beneath the lowermost pulmonary vein, down to the apex of the *pouch-like* pervious portion of the primitive vein (Plate III. figs. 4, 5, 6; Plate IV. figs. 7, 8, 10, *c''*, and 9, *l*). By the period of birth (fig. 11), this opaque streak (*l*) has usually become interrupted or obscured.

#### *c. Concurrent and subsequent Changes in the Pervious Vessels.*

Contemporaneously with the shutting off of the left primitive venous channels, the cross branch in the neck (Plate III. figs. 1 to 6, *d*) enlarges and, together with a short portion of the left primitive vein below the entrance of the left subclavian, forms the *left innominate vein*; a small piece of the right primitive jugular, included between the entrance of the right subclavian and the junction with the cross branch, becomes the *right vena innominata*; whilst the remainder of the right primitive jugular, below the cross branch, together with the corresponding canal of CUVIER, becomes widened and forms the *superior vena cava* (*h*). At the junction of its two constituent parts, the vena cava receives the metamorphosed right cardinal vein, now the *vena azygos*, in which the right superior intercostal vein generally ends.

The metamorphosis of the pervious vessels on the *left* side is much more complicated.

*Outside the pericardium.*—In one embryo already mentioned (Plate III. fig. 4), the left primitive jugular vein was converted into a cord ( $c''$ ), quite up to the cross branch or left innominate vein; and in that instance no trace whatever could be detected of the left cardinal vein. In such cases as the one referred to, the left superior intercostal vein may be subsequently formed through the development of small collateral veins, or it may be entirely wanting,—its intercostal branches ending then in some other vessels. Usually, however, a piece of the left primitive jugular vein, immediately below the cross branch, remains pervious and constitutes the trunk of the *left superior intercostal vein* (fig. 5,  $i$ ), which passes over the side of the aorta at a higher point, as the thorax becomes elongated during development. The left cardinal vein may be entirely withered, but in some cases (fig. 7) the left primitive jugular remains open from the cross branch quite down to the commencement of the canal of CUVIER, where it receives the diminished left cardinal vein ( $b'$ ), thus metamorphosed into the lowest branch of an unusually large left superior intercostal vein ( $i$ ). This vein, besides intercostal branches, may be very early found to receive thymic, pericardiac and mediastinal branches, and often a bronchial vein. In all cases, however, the left cardinal vein is effectually cut off from the occluded left canal of CUVIER ( $c''$ ), and is lost or interrupted at its lower part, so that the left intercostal system becomes broken up into several streams.

*Within the pericardium.*—The pouch-like pervious portion of the left primitive vein, seen on the back of the left auricle (Plate III. figs. 4, 5, 6,  $c'$ ; Plate IV. figs. 7, 8,  $s$ ), is metamorphosed partly into a small *oblique auricular vein* (Plate IV. figs. 9, 10, 11,  $o$ ), and partly into the *coronary sinus* ( $s$ ).

On examining the back of the heart in a series of early embryos (Plate IV.)\*, it will be seen, as already noticed in the Sheep, that in accordance with a certain twisting which takes place in this organ, important peculiarities in length and direction are early impressed upon the two canals of CUVIER, which are originally quite symmetrical. The right canal (figs. 1, 3, 5,  $c$ ), or future superior cava, passes down perpendicularly from the neck, becomes widened and shortened, soon reaches the future right auricle, and enters by a wide orifice into the upper part of that cavity, nearly in a line with the inferior cava ( $e$ ). The left canal ( $c'$ ), whilst diminishing in size, pursues a more circuitous course along the left auricular cavity, beneath the base of the heart, to reach the lower and left part of the future right auricle, into which it opens by a constricted orifice surrounded by an opaque well-defined border.

Even at a very early period, when this left canal of CUVIER has scarcely begun to shrink, its lower part is found, on cutting it open (figs. 2, 4), to be a *distinct vascular tube*, applied to and connected with the back of the future left auricle, but not opening into that cavity; whilst its orifice maintains its connection with the right portion of

\* All the figures in this Plate, excepting fig. 11, are enlarged to two diameters.

the yet undivided auricle, and is drawn with it, in the general movement of the heart, over to the right side. This being premised, it is easy to follow the changes which the lower pervious portion of the left canal of CUVIER undergoes, after the complete occlusion of its upper part, represented now by the opaque streak (fig. 9, *l*) on the wall of the left auricle, and by the minute fold of the pericardium (*v*) already described. For a time, the lower part of this canal persists as a conical pouch (Plate III. figs. 5, 6, *c'*); but subsequently (Plate IV. figs. 7, 8, from an embryo,  $2\frac{1}{2}$  inches long) this conical venous channel becomes elongated; its upper part forms the *oblique vein* already mentioned, whilst its lower part (*s*) pursues its course to the right along the auriculo-ventricular furrow. The coronary vein (*g*), properly so called, is now seen to end, not in the right auricle itself, but *in this venous channel*, falling into its under side at an acute angle, at a short distance from its termination in the auricle. Still later, in a foetus 5 inches long, from vertex to coccyx, the same facts are as plainly observed (figs. 9, 10); and on cutting open the veins at this period, a *narrow oblique venous channel* (*o*), tapering to a point as it ascends to the left along the back of the auricle, may be traced from the point of entrance of the true coronary vein (*g*) upwards to the opaque streak (*l*), seen on the wall of the auricle; whilst below the entrance of the coronary vein, the venous channel becomes *dilated* (*s*) as it passes to the right, receives several cardiac veins, including generally the middle cardiac, and ends in the lower part of the right auricle, close to the interauricular septum, by a somewhat contracted orifice, which is guarded by a rudimentary valve. This wider lower portion of the persistent venous channel can even now be recognized, in all respects, as the *coronary sinus*, and the valve beginning to form at its auricular orifice is the Thebesian valve. The opening of the true coronary vein into it is marked by a sharply-ridged margin, but as yet there is no valve there.

As development advances to the full period of foetal life (fig. 11), the proper coronary vein (*g*), and the coronary sinus (*s*), become gradually more continuous in direction than heretofore, but the difference between them can be easily discerned, even externally. The muscularity of the sinus, as distinguished from the vein, becomes evident, and the opening of the latter into the former is protected by a valve, the two segments of which are for a time narrower in proportion than in the adult. Above the entrance of this vein into the sinus, a rounded recess leads upwards and to the left into the *small oblique vein* (*o*), which, taking the course of the primitive vessel, of which it is evidently the remnant, runs along the back of the left auricle, about half-way to the root of the pulmonary veins, and there ends in the opaque streak (*l*) previously mentioned. This small oblique vein is crossed superficially by the muscular fibres of the left auricle; it is peculiarly straight in its course, and receives tortuous branches from the walls of the auricle.

d. *Changes which take place at Birth.*

The shrinking of the ductus arteriosus, and the simultaneous enlargement of the pulmonary artery and veins and of the left auricle, are accompanied by changes in the intrapericardial remnants of the left primitive vein. The pericardial fold is, as it were, invaded by the enlarging pulmonary vessels, and becomes relatively shorter, and more deeply concealed between the left pulmonary artery and the subjacent vein. The narrow opaque streak running around the root of the pulmonary vein and along the back of the left auricle, pursues a longer course, and becomes attenuated or broken up. Lastly, as the left auricle expands, the oblique vein is less evident, and the true coronary vein and the coronary sinus become more alike to each other in direction and diameter.

*Vestiges in the Adult Condition* (Plate I. fig. 1, Plate V.).—The relation of the left superior intercostal vein to the primitive vessel in different cases has been already noticed. Commencing from the trunk of this vein (Plate V. i), there may frequently be traced a few *vertical fibrous bands* (*f*) lying beneath the pleura, posterior to the phrenic nerve, and usually accompanied by small blood-vessels and by a fine branch of the vagus nerve (13). Generally one of these bands may be actually followed to the left superior intercostal vein; and in most cases they are continued downwards through the pericardium into the pericardial fold.

This fold (Plate I. fig. 1, and Plate V. v), which might be named the *vestigial fold of the pericardium*, may be compared to the broad ligament of the liver, after the closure of the umbilical vein. As far as I know, it has hitherto escaped attention, though it is probably always present in the ordinary condition, as I have found it in twenty-two adult hearts\*. In one instance, it could not be distinguished in consequence of complete adhesion of the pericardial surfaces, and in another, adventitious bands of membrane occupied its usual position. Sometimes it is obscured by fat, deposited within or near it. To demonstrate this vestigial fold and the opaque streak continuous with it below (which are almost unavoidably injured by dividing the great vessels within the pericardial sac), the heart, great vessels and pericardium, should be removed in connection with the root of the left lung; after which, on opening the pericardium and drawing asunder the left pulmonary artery and the subjacent pulmonary vein, the fold will be seen passing nearly vertically across the deep interval between those vessels (Plate V. v). Besides a duplicature of the serous layer of the pericardium, including cellular and fatty tissue, the vestigial fold contains some fibrous bands, small blood-vessels and nervous filaments. Its opaque well-defined and curved margin is commonly from half to three quarters of an inch in length, but I have once found it measure upwards of an inch and a half. It varies in thickness in different

\* SENAC states (*Traité du Mouvement du Cœur*, &c. Paris 1749, p. 14) that HALLER, in his account of the reflections and cornua of the pericardium, following EUSTACHIUS and LANCISI, has described, amongst many others, a falciform process (*fauix*) between the left pulmonary artery and veins; but I can only find in HALLER a description of a "saccus" or depression between those vessels.

cases, and it may be from half an inch to an inch in depth, according to the nature of the interval between the pulmonary artery and vein. Above the pulmonary artery, the vestigial fold blends with the pericardium, and its fibrous bundles may frequently be traced into those already described as passing beneath the pleura up to the left superior intercostal vein. Its lower end is lost on the side of the left auricle in the *narrow opaque* and often interrupted *streak* (*l*), which courses around the root of the lower left pulmonary vein. This streak represents the part of the left Cuvierian canal which has undergone the greatest amount of obliteration, and it is sometimes almost entirely wanting. In the same situation scattered whitish bands are commonly seen beneath the serous membrane of the back of the left auricle, closely connected with the muscular fibres and descending towards the oblique vein: amongst them there are some fine branches of nerves. They mark only the *track* of the previously existing vein. In some instances a prominent ridge exists in their place upon the back of the auricle.

The *small oblique auricular vein* (*o*), which has been shown to form part of the previous portion of the left canal of CUVIER, is remarkably constant; and indeed has been recognized by some of the early anatomists as a branch of the great coronary vein\*. This short vessel is readily distinguishable from its tributary branches by its direct course, a character not possessed by the cardiac veins generally. Moreover, it is as it were imbedded in the walls of the left auricle, so that it appears covered by muscular bundles, like the coronary sinus itself. Frequently it measures from half an inch to an inch in length, and sometimes is as large as a crow-quill, but more commonly it is smaller, and will admit only the head of a pin. I have once seen it an inch and a quarter in length, and as wide as a common goose-quill; but, however large it may be, its opening into the coronary sinus is never provided with a valve. Its upper end either tapers and ends in a fine branch; or, as more frequently found, especially in young subjects, it does not alter much in width as it ascends, but terminates rather abruptly, and receives, close to its extremity, one or two tortuous lateral branches of nearly equal size.

In some instances I have found a long slender vessel ascending from the upper part of this short vein, along the back of the auricle into the vestigial fold, and ultimately through the pericardium, just above the root of the left lung. It there joins

\* It is represented by RUYSCH (Thesaur. iv. tab. 3. fig. 1), and also by SENAC (*op. cit.* planche 2). HALLER (Oper. Minora, t. i. lib. i. p. 11) speaks of one particular branch of the great coronary vein coming from the left auricle. THEILE (SOEEMMERRING'S Anatomy) has a similar statement. This small vein has also been occasionally indicated in drawings of the heart given for other purposes; and it may be seen readily in most injected hearts preserved in anatomical museums.

VIEUSSSENS (Traité du Cœur, pp. 2, 55, planche 1. fig. 2, and planche 5. fig. 2) mentions and represents in two instances, as if ordinarily present, a large branch of the coronary vein in the situation of this oblique vessel, which he describes as returning the blood from the pericardial sac. HALLER remarks (Op. Min., t. i. lib. i. p. 11, note) that he has never seen this *vein of the pericardium*, which is certainly represented by VIEUSSSENS, both longer and wider, than, according to my experience, the oblique vein ever is in the *human* heart.

a small branch descending from one of the veins accompanying the phrenic nerve, and so is connected with the left superior intercostal vein. This slender vessel, which receives many little branches along its course, is not however part of the metamorphosed left primitive vein, but is formed by the enlargement of the minute inosculating veins of the parts which occupy the position of the obliterated vessel. In one case indeed, which was carefully dissected, the lower end of this small vein was found not to coincide with the trunk of the oblique auricular vein, but to fall into one of the lateral tortuous branches of that persistent vessel.

The arrangement of the valves in the *coronary sinus* in the adult has been fully described in the introduction to this paper. The abrupt commencement of the sinus, pointed out by Dr. J. REID, is owing to a rounded recess, formed on the auricular side of the principal valve (Plate I. fig. 1, *x*), into which the unvalved orifice of the short oblique vein (*o*) is *constantly* found to open. The sinus itself is described by the same observer as having "the appearance of a muscular reservoir placed at the termination of the (coronary) vein, similar to the auricles (auricle?) at the termination of the two cavæ;" but its relations to the left primitive vein in the embryo, and its analogies in the lower animals, have not hitherto been mentioned by anatomical writers; though Professor SHARPEY has been accustomed to point out, in his lectures, the resemblance between the coronary sinus and the lower end of the left superior cava.

## II. COMPARATIVE VIEW OF THE GREAT ANTERIOR VEINS IN MAN AND MAMMALIA.

Our knowledge of these veins in most of the Mammalia is still deficient, and many of the descriptions which exist are incomplete in points of detail. To the information gathered from other sources, I may add the results of observations made by myself on the veins of the Hedgehog, Rabbit, Rat, Mouse and Bat; of the common Mole, the Sheep, Ox, Hog, Guinea Pig and Horse; and of the Polecat, the Seal, the Dog, the Cat and the Monkey\*.

\* Since the observations and deductions contained in this paper were completed, and the paper itself entirely written, I have seen in the 4th and 5th No. of MÜLLER's Archiv for 1848, a short but very interesting communication by Dr. BARDELEBEN of Giessen, entitled "Ueber vena azygos, hemi-azygos und coronaria cordis bei Säugethieren," in which, after classifying the different Mammalia according to the condition of the *Azygos* and *Hemi-azygos* veins, as observed by RATHKE (*op. cit.* 1838) and himself, into four groups,—viz. I. those having neither of these veins; II. those having both; III. those having an azygos only; and IV. those having a hemiazygos only,—he arrives, from a comparison of the adult condition of the veins in the different cases, at the same conclusion as myself in regard to the analogy of the coronary sinus with the lower part of the left vena azygos or left vena cava superior. "If," he says, "the left canal of CUVIER continues in connection with the left jugular vein, so as subsequently to form the left vena cava superior, the coronary vein is said to open into the left superior cava. If all the blood is conveyed across the neck by the anastomosing branch between the left and the right jugular veins, and the portion of the left jugular between this cross branch and the left canal of CUVIER disappears, the last-named vessel continues to be connected with the intercostal system only; and then the coronary vein may be said to end in the left or hemi-azygos, or *vice versâ*. Finally, this connection of the left canal of CUVIER being also obliterated, there remains only that portion of the vessel in which



All the varieties of arrangement hitherto observed in the great anterior veins of the Mammalia may be classified according to the amount of deviation which they present from the type, pointed out by RATHKE, as originally common to all the Vertebrata, viz. that of four lateral primitive trunks.

The modifications of this type observed in the cold-blooded Vertebrata are strictly of a subordinate kind, affecting merely the relative size which particular vessels ultimately acquire. Even in birds there is no fundamental deviation from the original type. The four primitive lateral veins persist. No transverse branch is formed across the root of the neck, though a free communication exists between the jugular veins just beneath the skull. The right and left superior cavæ remain independent of each other as originally laid down, and each receives its own azygos vein.

Amongst the Mammalia, however, there appears to be no instance in which some change from the common primitive type does not take place. Throughout the whole class, so far as is known, there is the addition of a communicating branch across the root of the neck, between the two anterior primitive venous trunks. It is found even in the low bird-like Monotremes; and, should it prove to be universal, it will constitute one characteristic mark of the mammalian venous system.

The formation of this transverse communicating branch, which of necessity *precedes* the occlusion of the left primitive vein in the higher mammalian embryo, appears as the first, the simplest and the only change in the lowest forms of the mammalian series. Superadded to this preliminary step in the foetal development, and superadded also in the highest forms of adult Mammalia and in Man, is found another change, depending on one of two modes of partial occlusion of the left anterior primitive venous trunk.

In this way *three* different permanent conditions arise. In all of them the transverse communication in the neck exists. The right venous trunk always constitutes the vena cava superior of that side; but the left vein either forms,—A, a similar large venous trunk on that side, named a left vena cava superior, which receives the left jugular and subclavian veins, the left intercostals and certain cardiac veins; or B, it is reduced to a smaller left venous trunk, which receives merely the left intercostal veins and some cardiac veins; or, C, it remains as a still smaller vessel, receiving only a few cardiac veins from the substance of the heart. These three conditions accordingly are distinguished by severally presenting—

A. A right and a left vena cava superior.

B. A right vena cava superior and a left azygos venous trunk.

C. A right vena cava superior and a left cardiac venous trunk or coronary sinus.

the veins from the substance of the heart terminate, and which will then be recognized as the great coronary vein. This is the condition in Man and in most Mammalia. In fact, in no mammalian does the left canal of CUVIER entirely disappear. Even in cases where by far the largest portion of it is obliterated, that part which runs along the posterior transverse furrow of the heart remains as the trunk of the cardiac veins." I have availed myself of Dr. BARDELEBEN'S memoir, to introduce some additional examples of varieties of the great veins in animals.

Group A. *A right and a left vena cava superior*.—This condition exists in a large number of the lower Mammalia, viz. in the Monotremata\* and Marsupialia†; in most Rodentia, as in the Dormouse\*, Marmotte\*, Rat‡§, Echimys\*, Mouse‡§, Squirrel\*‡, Beaver\*, Hamster\*, Mole of the Cape\*, Hare‡ and Rabbit\*§‡. It is found also in the Elephant\*|| amongst Pachydermata; and in the Hedgehog‡§ and Bat\*‡§ amongst Insectivora and Cheiroptera.

In all such cases, the cross branch in the neck, when sought for, has been found. The left vena cava superior always descends in front of the root of the left lung, and then turns beneath the base of the heart, and after receiving the great coronary and other cardiac veins in its course, opens into the right auricle¶.

Owing to *subordinate* modifications in the azygos veins, this group may be again subdivided as follows:—

a. An azygos vein on each side.

a. Of equal size.

*Ex.* Monotremes. Marsupials (?).

b. Of unequal size.

α. Left azygos the larger.

*Ex.* Hedgehog\*\*, Rat, Mouse\*\*.

β. Right azygos the larger.

*Ex.* Rabbit.

b. An azygos vein on one side only.

a. A left azygos only.

*Ex.* (?).

b. A right azygos only.

*Ex.* The Squirrel. The Hare. The Rabbit is a near approach to this condition, the left azygos being very insignificant.

c. Azygos vein wanting (?).

Group B. *A right vena cava superior and a left azygos venous trunk*.—This arrangement prevails in most of the larger quadrupeds. It occurs in the Ungulates, Rumi-

\* MECKEL (Anat. Comp. par Jourdan, t. ix.) is the authority for including these animals.

† MECKEL. Also OWEN (Cycl. Anat. and Phys.).

‡ RATHKE (Dritter Bericht, &c. Königsberg, 1838).

§ The Author.

|| Mus. Anat. of University Coll. and of Royal Coll. of Surg. London.

¶ In the Marsupialia, and also in the Monotremata, the left upper cava joins the inferior cava just before that vein expands into the right auricle (OWEN, Articles *Marsup.* and *Monotrem.* Cycl. Anat. and Phys., vol. iii. pp. 307, 309 and 390). This peculiarity, which is particularly marked in those marsupials which have a large vena cava inferior (owing to the size of their hinder limbs), appears to be due merely to an opening out, as it were, of the orifices of the two veins, so that they meet and blend with each other.

\*\* EUSTACHIUS (Opuscula Anat. de venâ sine pari, p. 273) describes the large left azygos of the Hedgehog and Mouse, and also a splitting of the inferior cava, in the former animal, into two branches, of which one is evidently the left upper cava.

nants and Solipeds, as illustrated in the Hog\*†, Wild Boar and Guinea Pig†; in the Sheep\*†, Goat\*‡, Ox\*†, Dicotyles‡ and Moschus javensis‡, and in the Horse†. It is also present in the common Mole†.

The cross branch in the neck is necessarily present and forms the left innominate vein. The left azygos trunk arching over the root of the corresponding lung, descends in front of it and then turns (like the left vena cava superior in the former group) beneath the base of the heart to reach the right auricle, being first joined by the great coronary and some other cardiac veins.

Several gradations in the size of this left azygos trunk are met with in this group, which further observation on recent animals would probably render more complete, and which conduct by degrees to the third group, where the left venous trunk, reduced to its smallest persistent remnant, receives only veins from the substance of the heart.

Thus in the Hog, the left azygos trunk is very large, and returns the blood not only from its own side, but from the lowermost intercostal spaces of the right side also‡. In the Sheep and Ox it is, comparatively speaking, smaller. Finally, in the Horse, it is reduced to a very fine vessel, so that the left venous trunk conveys scarcely more than the blood from the cardiac veins; and in one case I found it quite closed as it passed along the left auricle||.

This gradual diminution of the left azygos trunk is accompanied by an equivalent increase in the size of the right azygos vein. For example: the right azygos is small and sometimes even wanting in the Hog; it is always an insignificant branch in the Sheep; it is very evident in the Ox; and very large in the Horse. In the last-named animal it returns most of the blood from the left intercostal spaces also, and thus exhibits the reverse of the condition observed in the Hog; and approaches, in this respect, the characters of the third and last group¶.

\* EUSTACHIUS (*op. cit.* p. 273) describes the left azygos in the Ox, Goat, Sheep and Hog, as passing over the left bronchus, and states that the coronary vein ends in it. BARTHOLINE, THOM. (*Hist. Anat.* 84. Cent. ii. p. 322) appears to have seen the left azygos in the heart of a lamb. LANCISI (*Epist. de venâ sine pari*, MORGAGNI's *Advers. Anat.* V. p. 80) mentions the left vena azygos in the same animals as named by EUSTACHIUS. RIDLEY (*Observat. Medic. Pract.* p. 219. In vitulo) says that, in the Sheep and Calf, the azygos is a *left* vein, which he imagined emptied itself into the left auricle or left pulmonary vein. SCARPA (*Tabulæ Neurolog.* tab. 7. fig. 4) mentions and also figures the left azygos vein in the Calf "ending in the trunk of the coronary vein."

† The Author.

‡ BARDELEBEN.

§ Correctly described by LANCISI (*op. cit.* p. 80).

|| It is said by RATHKE to be absent in the Horse; and by BARDELEBEN in the Ass.

¶ The transition from this to the third group is exemplified not only in the Horse and Ass, among Solipeds, but also in the Ruminantia; for I find that in the injected heart of the Camel (Museum of the Royal Coll. of Surgeons, London, Preparations 111, 112), the only trace of a left azygos visible consists apparently of a rather large oblique branch of the coronary vein on the back of the left auricle. The injected heart of the Tapir (Mus. Royal Coll. Surgeons, Preparation 105), in which animal BARDELEBEN says the left azygos is wanting, also exhibits a similar condition, the oblique vein being so large that it may be a rudimentary left azygos vein.

Group C. *A right vena cava superior, and a left cardiac venous trunk or coronary sinus.*—This arrangement prevails in the higher Mammalia, as in the Whale\*, Dolphin\* and Porpoise\* among Cetacea, in the Seal†, Walrus\*, Dog†, Cat†, Tiger‡, Hyæna‡, Polecat† and Ermine‡ among Carnivora, in the Quadrumana, as for example, in two small species of Monkey†; and lastly, in the human subject.

The left primitive trunk, now reduced to a cardiac vein, forms the *coronary sinus*, with its *small oblique branch* on the back of the left auricle, and having received the great coronary and some other cardiac veins, opens into the right auricle. The oblique vein is more or less evident in different cases. Thus it is large in the human subject; very apparent in the Dolphin, smaller in the Porpoise and the Dog, less evident in the Whale and Walrus, and very small in the Seal, Cat and Tiger§. The *vestigial fold* is more distinct in Man than in any animal which I have hitherto examined in the recent state; but it is readily seen in the Monkey, Dog and Cat.

Almost invariably the right azygos persists, whilst the lower intercostal veins of the left side, instead of forming a left azygos venous trunk, unite into an azygos minor which joins the right azygos. Variations in the extent of the azygos and azygos minor constitute subordinate peculiarities. In the Cetacea||, the remarkable condition is found of total absence of the right azygos as well as of the left azygos vein.

*Peculiarities of the coronary vein and sinus in certain animals.*—In the Ornithorhynchus, in which animal the left superior cava joins the inferior cava immediately before its termination in the right auricle, the coronary vein is said to open directly into the auricle by a separate orifice *to the right* of the inferior cava¶. It seems not improbable that in this case the vein in question is rather a *posterior cardiac* vein, ascending upon the back of the ventricles, the vessel in the ordinary position of the coronary vein being diminished in size or absent. In very small animals having a left anterior venous trunk, as in the Mouse and Bat, I have observed that this condition exists\*\*.

The arrangement of the valves of the coronary and other cardiac veins at their respective terminations in the coronary sinus, the left azygos trunk or the left vena cava superior, has already been examined and compared (pp. 133, 134). As to the Thebesian valve, it is present in every instance in which the left venous trunk forms

\* Preparations in Mus. Royal Coll. Surg. Lond.: Whale, No. 135; Dolphin, No. 127; Porpoise, No. 130; Walrus, No. 76; Tiger, No. 68: also Mus. University Coll. Lond.

† The Author.

‡ BARDELEBEN.

§ Some of these observations have been made only on dried injected hearts.

|| VON BAER (Nova Acta Acad. Cæs. Leop. Carol. vol. xvii. p. 408), also heart of the Whale, Mus. Royal Coll. Surg. Lond. Prep. No. 135.

¶ MECKEL (quoted in Prof. OWEN's Art. *Monotremata*, Cycl. Anat. and Phys. p. 390).

\*\* It is also seen in the small heart of the common fowl, though in the larger heart of the Ostrich the coronary vein occupies its usual position and opens into the left superior cava (OWEN, Art. *Aves*, Cycl. Anat. and Phys. vol. i. p. 330).

a coronary sinus receiving veins from the heart alone, as in Man, and in the Monkey, Dog and Cat: but amongst those animals which have a left azygos or left superior cava, it is certainly absent, as in the Calf, Hog, Sheep, Horse, Ass\*, Rabbit and Hedgehog.

### III. ANALYSIS OF THE VARIETIES OF THE GREAT ANTERIOR VEINS IN MAN.

The different conditions of the great anterior veins in the Mammalia having been classified according to their progressively increasing deviation from the common vertebrate type, an attempt may be made, in analysing the varieties of these vessels met with in Man, to retrace the series from forms presenting the most complex metamorphosis to such as manifest no fundamental change whatever. In this series the ordinary condition of the veins is included as the *most frequent* actual variety.

The formation of the cross branch at the root of the neck being regarded as the initial step in the metamorphosis of this portion of the human as of the mammalian venous system, the varieties of these veins in Man may be divided into two classes, according to the *presence* or *absence* of this transverse branch.

The occurrence, in one or another degree, or the entire failure of the subsequent stage of the metamorphosis, viz. the occlusion of one of the lateral primitive veins, suffices to distinguish the *first* class of varieties into three groups, corresponding with those already indicated as the regular conditions in different Mammalia. A. In the first group, comprehending the normal condition, in which the occlusion is of the greatest known extent†, the persistent portion of the vein, after metamorphosis, conveys only the blood from the substance of the heart, and forms a *cardiac venous trunk*. B. In the second, it would also return the blood from its own side of the thorax, and thus constitute an *azygos venous trunk*. C. In the third, where no occlusion occurs, it transmits the blood from the whole of its own side of the upper part of the body, and is then a *second vena cava superior*.

In all of these cases, one of the lateral primitive veins is developed into the ordinary vena cava superior, and in most instances this is the vein of the right side, whilst that of the left undergoes metamorphosis; but the reverse of this may happen, as

\* REID (Art. *Heart*, Cycl. Anat. and Phys. p. 597).

† It has already been shown that *complete* occlusion of this primitive vein (*i. e.* from the neck down to its entrance in the right auricle) does not (as RATHKE supposed) occur, in the ordinary condition, even of the highest Mammalia or of Man, nor has it yet been seen as an occasional variety. That it ever does happen is scarcely probable; for just as in the utmost known amount of abnormal obliteration of the inferior cava, the hepatic veins always concur to form a short inferior trunk, which opens into the right auricle, so the confluence of the coronary and other cardiac veins may set a like limit to the occlusion of the left anterior primitive venous trunk. Nevertheless, it is possible that the process might extend to the closure of its lower end or coronary sinus also, the blood from the substance of the heart then returning to the right auricle directly through enlarged anterior or posterior cardiac veins, or taking some altogether different course. In a curious case recorded by LE CAT, and hereafter to be particularly mentioned, the auricular end of the left primitive vein seems really to have been closed, though its channel continued pervious up to the neck.

when the viscera are transposed; so that *transposition*, as an additional cause of peculiarity, may affect any of the preceding groups.

Lastly, the three principal groups may present subordinate variations, depending on peculiarities either in the upper vena cava itself, or in the azygos veins, or in the coronary vein of the heart.

In the *second* class of varieties, in which no cross branch is formed in the neck, both of the lateral primitive veins are necessarily persistent, each carrying back the blood of its own side. Such cases may also present peculiarities in the azygos system, or may be complicated by transposition of the heart.

Though the records of the varieties in these great veins in the human subject do not as yet supply examples of every conceivable deviation, and though the descriptions of many are somewhat obscure or incomplete, they appear to admit of arrangement according to the scheme just mentioned.

#### CLASS I. TRANSVERSE BRANCH IN THE NECK, PRESENT.

Group A. *The second anterior venous trunk reduced to a cardiac venous trunk.*

a. *Without transposition.* A right vena cava superior, and a left cardiac venous trunk or coronary sinus.—This is the ordinary condition of the great anterior veins. It is accompanied by numberless subordinate modifications, occurring either in the right superior cava itself, or in the azygos systems, or in the coronary vein of the heart, and includes by far the greater number of the recorded varieties of these veins.

##### a. *Varieties in the Right Superior Vena Cava.*

These appear to be very rare. A presumed example is recorded by ROSENTHAL\*, in which, the auricles and ventricles being undivided, two superior veins, called two superior cavæ, joined immediately before ending in the single auricle, into which however they opened by separate mouths. In this case the upper cava may have been shorter than usual, so that the two superior veins were the venæ innominatæ; but the description is not sufficiently full†.

##### b. *Varieties in the Right and Left Azygos Systems.*

These are exceedingly numerous, and require to be referred to several heads:—

1. *The right intercostal system consolidated, the left intercostal system broken up.*—In this, the most frequent arrangement, the right intercostal veins end principally in the azygos vein, but partly also in a right superior intercostal vein. The left inter-

\* Abhandl. aus dem Gebiete der Anat. Physiol. und Pathol. Berlin, 1824, p. 150.

† It may be here mentioned that WEESE (De Ectopia Cordis, &c. 1818, Berolin. sect. 37, 48) has twice found the left innominate vein (the primitive cross branch) in malformed fœtuses, passing across the neck behind the trachea and œsophagus.

costal system loses its integrity as development goes on; its middle and lower portions end in the azygos vein, either through an azygos minor, as in the usual case, or if that vessel be wanting, by independent intercostal branches\*, or by both of these ways together†; or its lower branches may descend to the lumbar or renal veins‡. Its upper portion forms a left superior intercostal vein.

The azygos vein, in these cases, formed towards its termination by the persistent trunk of the right cardinal vein, usually ends in the upper vena cava (the right canal of CUVIER), but its place of termination is said, though very rarely, to be moved on, as if by the fusion of the canal of CUVIER with the right auricle, so that it may end in the auricle itself§, or even approach the neighbourhood of the inferior cava, within the pericardium§(?), as occurs in some animals.

The right superior intercostal vein, which is not formed by any part of the primitive venous trunks, frequently joins the arch of the vena azygos itself||; but, without any other coexistent variation, its place of opening may be removed to the upper vena cava||, to the right innominate||, or subclavian veins¶, or even to the vertebral vein\*\*.

The left superior intercostal vein, the trunk of which is generally formed by the metamorphosed portion of the primitive left jugular vein, immediately below the transverse branch in the neck, is, when present, almost constant in its mode of termination, ending at the underside of the commencement of the left innominate vein††.

2. *The right intercostal system retaining its integrity, but unusually large.*—There are various degrees of this condition, in which the azygos vein, besides receiving all the intercostal branches of its own side, including the superior intercostals, is joined by more than usual, or even by all the separate branches of the left side‡‡. In this latter case the ordinary left superior intercostal vein is very small or wanting, the left primitive jugular trunk having become obliterated quite up to the cross branch in the neck, as exemplified in the embryo, Plate III. fig. 4.

A still more remarkable enlargement of the azygos vein has been rather often met with, in those cases in which, the inferior cava being deficient, the azygos conveys all the blood usually brought back by that vessel excepting what returns from the liver, which continues to pass by a short hepatic venous trunk directly into the heart. The

\* SOEEMMERRING (*De Corporis Humani Fabricâ*, vol. v. p. 373).

† BRESCHET (*Recherches sur le Système Veineux*. Note, p. 8–10).

‡ CHESelden (*Philosophical Transactions*, 1713, vol. xxviii. p. 282). There is a doubt about this case, which is again noticed in p. 161. BRESCHET (*op. cit.* p. 9. note) in a child ten to twelve years of age. SOEEMMERRING (*op. cit.* p. 372).

§ SOEEMMERRING (*op. cit.* p. 376).

|| BRESCHET (*op. cit.* p. 12).

¶ HILDEBRANDT (*Lehrbuch der Anat. des Menschen*, 1803, vol. iv. p. 281).

\*\* HALLER (*Element. Physiol.* t. iii. p. 107; also t. i. lib. iv. pp. 308, 320).

†† HILDEBRANDT (*l. c.*).

‡‡ BRESCHET (*l. c.*; also pl. 1. livr. i.).

course of the lower part of this devious vein may vary; but above, it may always be identified as the enlarged azygos (originally the right cardinal vein\*).

3. *The trunks of the right and left intercostal systems nearly equal.*—The several modifications of this condition constitute the different varieties of so-called *double vena azygos*; but although the azygos minor or hemi-azygos is in all these cases much enlarged by consolidation of its parts, yet it must be carefully discriminated from that true form of left vena azygos which exists, for example, in the Sheep, and in some animals having a left vena cava superior.

α. In one set of these cases, the size and termination of the azygos vein itself being as usual, the azygos minor, enlarged and extending higher than ordinary, crosses over to the right side and joins the azygos vein near to or at its termination in the superior cava†, or ends in the upper cava itself‡, or even it has been said in the right auricle§. Most frequently, the azygos vein ending as usual, the enlarged azygos minor or left azygos, as it is often called, ascends on its own side and ends in the place of the left superior intercostal vein in the left vena innominata, as if by persistent connection of the left cardinal vein, with the short part of the left primitive jugular below the cross branch in the neck||.

\* 1. WINSLOW (*Exposition Anatomique*, &c. t. iii. pp. 119 and 157). This example, which is clearly described, seems to have been overlooked.

2. ABERNETHY (*Philosophical Transactions*, 1793, p. 69). The preparation is figured in Prof. QUAIN's *Anatomy of the Arteries*, pl. 5. fig. 5. The aorta arches over the right bronchus as well as the vena azygos.

3. WISTAR (*A System of Anatomy*, &c. Philadelphia, 1811–14, vol. ii. p. 320). This was originally regarded as an example of *absence* of the azygos vein, the enlarged vessel being considered as the inferior cava, rising higher up than usual, and ending in the vena cava superior. It is so quoted by GURLT (*ut infra*). The specimen was found in 1813, and afterwards given by WISTAR to Dr. HORNER, by whom it has been correctly described and explained in the *Journal of the Academy of Natural Sciences of Philadelphia*, 1818, vol. i. part ii. p. 407 (with a plate). OTTO (*Lehrbuch der Anat. Patholog.* p. 348, note 30) has been thus led to reckon it as two separate cases.

4. JEFFRAY. This preparation, mentioned by OTTO (*op. cit.* p. 348) as having been seen by him in the collection of Prof. JEFFRAY, is, as I am informed by Prof. ALLEN THOMSON, now in the Museum at Glasgow.

5. OTTO himself (*loc. cit.* and *seltene Beobacht.* p. 67) met with an instance, which was afterwards fully described and represented by GURLT (*De Venar. Deformatibus*, &c., 1819, p. 20).

6. WEBER (*Rust's Magaz.* &c. vol. xiv. p. 536).

† HALLER (*op. cit.* t. iii. p. 107), WINSLOW (*op. cit.* p. 121), SANDIFORT, three cases (*Observ. Anat. Path.* lib. ii. c. vii. p. 126, and lib. iv. p. 12).

‡ BLASIUS (*Observat. Anatom.* p. 116; also *Observ. Medic.* p. 53. tab. 7. fig. ii. 1711). SANDIFORT (*op. cit.* lib. iv. p. 98).

§ SYLVIVS, JACOBUS (*Opera Medica*, Geneva, 1635, p. 144). In the body of ANTONIVS MASSA, *Chirurgus*, two azygos veins were found, “*unam ab aure dextrâ, alteram inferiorem a cavâ cordi adapertâ.*” It is assumed by EUSTACHIUS (*Opuscula*, &c. p. 274) that this was an example of double azygos, one left and the other right, but the brevity and obscurity of the original account render it impossible to decide on its true nature.

|| Most of the cases recorded as examples of “double vena azygos” are of this kind. See EUSTACHIUS (*Opuscula Anat.* p. 274; and *Explicat. Tab. Anat.* by ALBINUS, tab. 4. figs. i. ii. iii.). LANCISI (*De Venâ sine pari*, in MORGAGNI's *Advers. Anat.* V. pp. 82, 87, 94). WINSLOW (*Expos. Anatom.* T. III. p. 121).



β. A variety of double vena azygos is described by BARTHOLINE, which may have been owing to the azygos and azygos minor, of nearly equal size, ending in the corresponding superior intercostal veins\*.

γ. In other kinds of double azygos, a right and a left vein coexist, and becoming widened below, discharge themselves in the lumbar or emulgent veins†.

4. *The right intercostal system broken up, the left more consolidated.*—In this somewhat rare condition, the trunk of the azygos vein is reduced to a very small vessel, ending as usual in the superior cava; but most of the right intercostal veins pass over to the left side, where they form a large left azygos ending above in the left innominate vein through the left superior intercostal‡.

5. *The right azygos vein entirely wanting.*—In all the preceding varieties of the intercostal system of veins, with their intermediate gradations (excepting β), the vena azygos is still present, though sometimes represented by a very small vessel. The persistence of the right cardinal vein is therefore remarkably constant. It is possible, however, to conceive this vessel to be entirely obliterated, so that there should be no vein arching over the right bronchus to end in the upper cava. No perfectly unexceptionable example of this condition has been recorded§.

### c. *Varieties in the Coronary Vein of the Heart.*

As might almost be anticipated, these are few and very rarely occur. One instance is mentioned by MECKEL and one by JEFFRAY in which the coronary vein ends in the left auricle||. The most unexpected deviation, however, is that in which the blood of the coronary vein reaches the heart through some remote vein instead of

MASCAGNI (Syst. Vas. Lymphat. tab. 19). HALLER (Element. Phys. t. iii. sect. i. p. 107). OTTO (*op. cit.* pp. 347, 348, notes 18, 20). WRISBERG (De Venâ Azygâ duplici, &c. 1778. Observat. 1 and 2). WILDE (Comment. Petropol. vol. xii. p. 318). BRESCHET (*loc. cit.* p. 9). LAUTH (Manuel d'Anatomiste. Paris, 1826, p. 592); and several other authors.

\* BARTHOLINE, THOM. (Hist. Anatom. 84. Cent. ii. p. 322. 1641). "I have often seen," he says, "in man and animals a double vena azygos, one on each side, leading from the axillary veins."

† EUSTACHIUS (Explic. Tab. Anat. xxvi. xxvii.). BRESCHET (*loc. cit.*).

‡ VALENTIN (Journal de Médecine. Paris, 1791, tom. 86, p. 238).

§ One is related by WRISBERG (*op. cit.* Observat. 3), which, he remarks, was unique in 200 observations; but it seems probable that the vein was here obliterated by the effects of pressure. There was no azygos ending in the upper cava, but all the blood from the right side passed into the left vein, which was very large, and joined the left subclavian opposite to the termination of the thoracic duct. The subject was a boy, aged five years. The right lung was changed into a solid substance (steatoma), and it was universally and firmly adherent. Large hardened bronchial glands were found along the right side of the trachea down to the bronchus. On the left side the lung was free.

|| MECKEL (Handbuch der Mensch. Anat. vol. iii. p. 67). The case is also described by LINDNER (Diss. de Lymph. Syst. Halæ, 1787, p. 21). JEFFRAY (Observat. on the Heart of the Foetus, p. 2). The preparation which exhibits this very remarkable deviation, is now in the Museum of the University of Glasgow, and has recently been carefully re-examined by Professor ALLEN THOMSON and Professor SHARPEY.

through the coronary sinus. LE CAT\* has recorded the following interesting variety, occurring in a child eight days old, in which he found "les veines coronaires réunies dans un seul tronc, qui sans pénétrer dans l'oreillette droite, se jettoit dans la veine souclavière gauche." The course pursued by this *single trunk* from the heart to the left subclavian vein is not described; and, anomalous as this remarkable case has hitherto appeared, it is, perhaps, an example of the closure of the orifice of the left primitive vein in the right auricle, accompanied by a pervious condition of that vessel up to the cross branch in the neck.

When the posterior cardiac vein is large and ends directly in the right auricle†, the great coronary vein and coronary sinus may be comparatively small, but instances of its extreme diminution, or entire absence, only occur with some other deviation‡.

b. *With transposition.* *The vena cava superior on the left side, and a coronary sinus on the right side.*—When the arch of the aorta passes over the right bronchus, the veins do not always suffer transposition also, for in those cases in which the aorta regains the left side of the vertebral column as it descends, the vena cava superior, together with the azygos, continues on the right side§. But in complete transposition of the viscera (including the heart and great arteries), the vena cava superior descends on the left side, and the azygos vein is transposed to that side also||. Here, the metamorphosis by occlusion has affected the right primitive veins, instead of the left; and, the heart itself being entirely transposed, it is presumable that there would be found, in a recent specimen, a right cardiac venous trunk, that is to say, a coronary sinus on the right side, receiving the great coronary vein, together with an oblique auricular vein, a *vestigial fold* and the other remnants of the occluded second primitive venous trunk, as in the usual case.

\* Mémoires de l'Acad. des Sciences, 1738, Hist. p. 44. This is a case already referred to in the note to p. 153. Dr. JOHN REID (Cyclop. Anat. and Phys. Article *Heart*, p. 597) has suggested that SÆMMERING had LE CAT's case in view, when he states (De Corp. Humani Fabr. vol. v. p. 340) "rarissime vena hæc in venâ subclaviâ *dextrâ* finitur," being probably misled by an inadvertence of HALLER, who, in quoting the case, has substituted the word "*dextram*" for "*sinistram*" (Elem. Physiol. t. i. p. 375, editio 1757). It may be added, that the termination of the coronary vein in the *left* subclavian is, as explained in the text, readily reconcileable with the mode of development.

† OTTO (*op. cit.* p. 347, n. 8) and other authors.

‡ In one instance recorded by LEMAIRE (Bull. des Scienc. Med. 1808, vol. v. p. 21), two coronary veins are said to have joined a pulmonary vein, and so reached the right auricle; but the facts seem to bear another explanation, the *pulmonary vein* in question being apparently a *left superior cava* descending in its wonted circuitous course beneath the root of the left lung, and receiving two cardiac veins as usual.

§ ABERNETHY (*loc. cit.*) and other cases by FIORATI, SANDIFORT, CAILLIOT, J. F. MECKEL, BERNHARD, OTTO, &c., quoted in QUAIN's Arteries, p. 18.

|| A specimen in the Museum of University College, which is described and represented in Prof. QUAIN's "Anatomy of the Arteries" (p. 17, plate 5. fig. 3). HALLER in the right fœtus of a double monster (De Monstri Dissection. i. 1739; Opera Minora, t. iii. p. 102). For references to other cases, see a paper by Dr. WATSON, Med. Gazette, June, 1836, p. 393. Also Mr. W. CLAPP, Med. Gazette, Jan. 1850.

Transposition of the great anterior veins may be further complicated by subordinate varieties, as for example, in the intercostal systems; and it is interesting to find that one of the most remarkable of the deviations met with in the azygos vein when holding its customary position, has been observed also in the transposed vein; viz. its excessive enlargement to enable it to return the blood from the lower half of the body, in cases where the inferior cava is deficient, and is represented only by the trunk of the hepatic veins\*.

Lastly, the great anterior veins do not appear ever to undergo transposition, unless the heart itself be reversed†.

Group B. *The second anterior venous trunk, an azygos venous trunk existing on the left side, or by transposition on the right.*—This condition, which is regular in the Sheep, Ox, Goat, Pig, &c., has not, as far as I know, been met with as a deviation in the human subject, even in the most complex forms of transposition or malformation; but it is here referred to as one that may possibly be yet detected‡.

In the cases hitherto recorded as examples of a left vena azygos in Man, the unusual vein, as already fully particularized (pp. 156, 157), has ended in some of the branches or in the trunk of the vena cava superior. A true left vena azygos, however, sometimes exists in the human subject, in connection with an additional superior cava, as will immediately be shown.

Group C. *The second anterior venous trunk, an additional vena cava superior.*

a. *Without transposition.* In these cases the heart and great vessels, as well as the other viscera, holding their usual position, the superadded vein is a *left superior cava*. This condition constitutes that interesting variety of the great anterior veins commonly named *double vena cava superior*, in which the arrangement of the vessels

\* HERHOLDT (Abhandlung der K. Acad. zu Kopenhagen, 1818).

McWHINNIE (London Med. Gazette, 1840). The preparation is in St. Bartholomew's Hospital Museum, and is figured in QUAIN'S "Anatomy of the Arteries," &c. (pl. 5. fig. 4). In both of these instances the transposed azygos receives all the branches of the inferior cava excepting the hepatic veins, and turns over the left bronchus to end in the ordinary upper cava, which, however, is on the left side.

† In an interesting case recorded by WILSON in the Philosophical Transactions, a vena cava superior, together with a perfect vena azygos, is found on the left side only of the thorax. This does not appear to have been an example of transposition of the right vein over to the left side; but rather one in which, the heart being reduced to a single auricle and a single ventricle and not transposed, the ordinary right upper cava is entirely wanting, whilst a true *left* upper cava alone exists, pursuing, as usual, a circuitous course to the heart (Philosophical Transactions, 1798, p. 346, with a plate). A case of ectopia cordis. The child lived seven days.

STANDERT (Philosophical Transactions for 1805, Part II. p. 228) gives an account of a child's heart, with undivided auricles and ventricles, in which the same condition of the veins, as far as can be understood from the figure, appears to have existed.

‡ Could the statement and figures of VIEUSSSENS (*loc. cit.*) be considered free from *all* doubt, the so-called *vein of the pericardium*, which returned the blood from the outside of that sac, and descended in the position of the oblique vein into the coronary sinus, might be conceived to have been a true left azygos venous trunk, formed by a persistent left canal of CUVIER (see p. 147).

resembles that observed in the Elephant, in many of the Rodentia, the Marsupials and some other Mammalia.

In these cases the ordinary right superior cava is smaller than usual, being assisted by the additional vein on the left side. This left upper cava, generally smaller than the right one, invariably descends over the aortic arch, and afterwards in front of the root of the left lung, beneath which it turns backwards and then runs along the base of the heart to reach the right auricle.

Nearly thirty examples of this condition are on record, and to that list I am enabled to add two more cases, which will be here described. For convenience of reference they may be tabulated in the following form.

*Tabular View of Examples of Double Vena Cava Superior in the Human Subject.*

Number in succeeding account.	Name of observer.	Date.	Sex and age.	Simple, or with other malformations.	Transverse branch present or not.	Azygos veins.	Figured or not.	Remarks.
0.	Bartholine ...	1641.	.....	.....	.....	.....	.....	A doubtful case.
1.	St. Thomas's	.....	Adult	.....	A cross branch?	Right.	.....	
2.	{ Bœhmer and Theune }	1763.	Male, 11 years...	.....	None	Right and left	Figured	
3.	Haller	1739-1762.	Fœtus	Double monster	None	.....	Figured	
4.	Murray	1781.	Female, 60 years.	.....	None	Right	Figured	
5.	Ring	1805.	Female, 1 year...	Auricles not divided	?	.....	Figured	
6.	Lemaire	1808.	Female, 30 years.	Auricles communicating	?	.....	.....	Rather doubtful case.
7.	Niemeyer	1814.	Fœtus	Much deformed	?	.....	Figured	
8.	Meckel	1816.	Fœtus	Monstrous	?	.....	.....	
9.	Meckel	1816.	Fœtus	Monstrous	?	.....	.....	
10.	Meckel	1818.	Fœtus	Monstrous	?	.....	.....	
11.	Meckel	1820.	?	.....	None (?)	.....	Figured	
12.	Béclard	1816.	Adult	.....	None (?)	Right and left (?)	.....	
13.	{ Bock and Cerutti }	.....	Adult	.....	.....	.....	.....	{ Original description not referred to. Ditto.
14.	Hesselbach	.....	Adult	.....	.....	.....	.....	
15.	Weese	1819.	Fœtus	Ectopia cordis.	?	.....	.....	Rather doubtful case.
16.	Weese	1819.	Fœtus	Ectopia cordis.	?	.....	.....	
17.	Weese	1819.	Fœtus	Ectopia cordis.	None	.....	Figured	
18, 19.	Wirtensohn	1825.	Fœtus, double	Monsters	None	Right	Figured	
20.	Wehrde	1826.	Fœtus	Monster	.....	.....	.....	{ Original account not referred to.
21.	Breschet	1827.	Male adult	.....	?	.....	.....	
22-24.	Breschet	1827.	Fœtuses	Ectopia cordis.	?	.....	.....	
25.	Otto	1830.	Fœtus	Malformed	?	.....	.....	
26.	Otto	1830.	Fœtus	Malformed	?	.....	.....	
27.	Otto	1830.	?	.....	?	.....	.....	
28.	Houston	1831.	Adult	.....	?	.....	.....	
29.	Sharpey	1844.	Adult	.....	A cross branch	Right and left	Figured	
30.	Author	1849.	Male, 56 years...	.....	A cross branch	Right and left	Figured	
31.	Author	1849.	Female, 5 years	Malformed	?	.....	.....	

Omitting BARTHOLINE'S case as doubtful, the thirty one remaining examples may be thus distributed. Sixteen have occurred in fœtuses more or less malformed; the age and condition of the subjects of two are uncertain; and, in two others, though the individual had lived in one case for a year, and in the other for five years, there was some accompanying defect in the heart; so that, including LEMAIRE'S case, not more than *eleven* examples of additional superior cava have yet been observed in the *adult*, uncomplicated by other deviations from the ordinary condition of the heart.

(St. THOMAS'S, BÖHMER and THEUNE, MURRAY, LEMAIRE (?), MECKEL, BÉCLARD, BRESCHET, OTTO, HOUSTON, SHARPEY, the Author\*.)

Only those examples of left vena cava superior can be included in the present group, in which the cross branch at the root of the neck has been duly formed, the instances in which that characteristic preliminary step in the development has not taken place, being referable to the *second* class of peculiarities of the great anterior veins. Unfortunately, the descriptions of most of the known examples of double vena cava superior are incomplete, particularly as regards the existence of the transverse branch in the neck, and the condition of the azygos veins.

In two instances only is the presence of the cross branch placed beyond a doubt (Nos. 29, 30)†.

In six cases, in which the vessels appear to have been examined and preserved sufficiently high up in the neck to have determined the point one way or the other, the cross branch seems as certainly to have been wanting (Nos. 2, 3, 4, 17, 18, 19)‡.

With regard to a *large number* of the examples, it is quite impossible, on reference to the descriptions or figures, to decide whether any transverse branch had ever existed or not (Nos. 1, 5, 7, 8, 9, 10, 11, 12, 16, 21, 22, 23, 24, 25, 26, 27, 28, 31)§.

\* ROSENTHAL'S case, already mentioned (p. 154), has usually been considered an example of additional left superior cava, but it appears rather to be one of prolonged subdivision of the right vena cava. LE CAT'S interesting specimen (p. 158) might be considered to have been an example of a small left upper cava, closed at its lower end.

† No. 29. Professor SHARPEY met with this specimen in Edinburgh in 1833 or 1834. The preparation (injected and dried) is now in the Museum of Anatomy of University College, London. It is represented in Prof. R. QUAIN'S work on the Arteries, &c. (pl. 58, figs. 9, 10, pp. 371, 432). In all respects in which it can be compared, it resembles the following case, No. 30.

No. 30. The Author's example, described in pages 162-164.

‡ The references to these six cases are given in pages 164, 165.

§ No. 1. In the Museum of St. Thomas's Hospital there exists a specimen of double vena cava superior. The preparation in question, No. 1178, is an adult heart, which has been injected and dried. The cavities, which are now empty, are laid open. The left vena cava superior is smaller than the right, excepting its intrapericardial portion, which is much dilated. There are indications of a transverse branch, but its existence cannot now be confidently asserted. The azygos vein, which is of ordinary size, opens as high as usual in the right superior cava. The middle cardiac vein opens directly into the auricle. The coronary vein appears to be small. There is no azygos visible on the left side. The wide orifice of the left cava has, on its upper and right border, a narrow ridge, but there is no Thebesian valve. A small perforated Eustachian valve exists. CHESELDEN (Philosophical Transactions, 1713, vol. xxviii. p. 282) has described "a heart with the vena azygos inserted into the right auricle, and the descending cava coming round the basis of the heart, above the aorta and pulmonary vessels, to enter the auricle at the lower part with the ascending cava." This case has usually been regarded as an example of double vena cava superior. The preparation at St. Thomas's, the history of which is not known, but which Mr. SOUTH informs me is one of the oldest in the collection, may possibly be the specimen described by CHESELDEN; but as his account is so brief, and no drawing accompanies it, the point must remain doubtful. There is a discrepancy between the specimen and the account in the Philosophical Transactions in regard to the termination of the vena azygos.

No. 5. RING (Med. and Phys. Journal. London, vol. xiii. 1805, p. 120, with two figures). The preparation is in St. Thomas's Hospital Museum. This case shows a right and a left superior cava, with want of sepa-

In three instances, no access has been had to the original descriptions (Nos. 13, 14, 20)\*.

The three remaining cases, though usually regarded as instances of superadded left superior cava, are somewhat doubtful examples of this variety (Nos. 0, 6, 15)†.

Further, the condition of the azygos veins is accurately known in only four cases (Nos. 2, 4, 29, 30).

In every instance, the course and connections of the left vena cava superior, so far as can be ascertained from the descriptions, correspond entirely. Reserving for the present the six cases in which the absence of the cross branch seems to be certain, I may here describe, as a characteristic example of double vena cava superior, accompanied with the cross branch, the specimen met with by myself.

The subject of this case (No. 30), a male aged fifty-six years, had not suffered from any disease of the heart. That organ is rather large: the right vena cava superior (Plate VI. *h*) is smaller than usual, and pursues its accustomed course to the ration of the auricles. Had the interauricular septum been formed, the left vein, which is now described as opening into the *left* auricle, would probably have had its orifice directed into the right auricle. Similar instances are recorded by WEESE and BRESCHET, Nos. 16 and 23, 24.

No. 7. NIEMEYER (De fœtu puellari edito abnormitatis exemplo. Halæ, 1814, cum fig.). The left cava superior is said to have descended to join the inferior cava, reminding one of CHESELDEN's description.

No. 8 to 11. MECKEL (Tabul. Anat. Path. 1820, tab. x. figs. 6, 7); two other cases (Hand. der Anat. Path. 1816, vol. ii. p. 125); and one (Archiv. f. d. Physiolog. vol. iv. p. 479, 480).

No. 12. BÉCLARD (Bull. de la Soc. de Med. 1816, vol. v. p. 115).

No. 16. WEESE (De Ectopia cordis, 1818, sect. 19). The same case is in WALTER's Museum Anat. P. i. p. 135, No. 826; and had been partially described by BUETTNER.

No. 21 to 24. BRESCHET (Le Système Veineux, 1827, p. 2, note 1). One example was in an adult male. Was this BECLARD's specimen? The other examples are in malformed fœtuses (Mém. sur l'Ectopie, &c.; and Répertoire d'Anat. et Phys., &c. t. ii. p. 12 and p. 17).

No. 25 to 27. OTTO (Beobachtung, ii. p. 69, and Verzeichniss, No. 2874). (Lehrbuch, &c., p. 344.) One example in an otherwise perfect subject. The two others in fœtuses malformed.

No. 28. HOUSTON's Catalogue of the Museum of the College of Surgeons, Dublin (vol. i. p. 58, B. b. 92).

No. 31. The Author. This heart, which is described at page 164, was presented to me by Dr. R. DAWSON HARLING.

\* These cases are referred to in OTTO's Lehrbuch der Pathol. Anat. 1830, vol. i. p. 347, note 13, as follows:—

No. 13. BOCK in CERUTTI's Pathol. Anat. Museum, B. i. H. 3. p. 50.

14. HESSELBACH, Beschreibung der Pathol. Präparate zu Würzburg, p. 229.

20. WEHRDE, Diss. Anat. Path. de Monstro rariore humano. Halæ, 1826, p. 11.

† No. 0. BARTHOLINE, TH. (Histor. Anatom. Montpelier, 1641, Hist. 84. Cent. ii. p. 322). This is quoted as an undoubted example by OTTO (*op. cit.* p. 347, note 13), but the statement of BARTHOLINE is not clear. He says, "that illustrious anatomist A. FALCOBURGH once showed me in a human dissection, an additional vein near the vena cava, similar to it, and which he considered a second cava."

No. 6. LEMAIRE (Bull. des Scien. Med. vol. v. 1808, p. 21). This (as already stated, p. 158) is described by LEMAIRE as an instance of the coronary vein ending in an *unusual left pulmonary vein*; but on careful perusal of the description, it appears more probable that the vein supposed to be pulmonary was really a *left vena cava superior*. There was a greater chance of error in this case, owing to there having been extensive adhesions of the pericardium.

No. 15. WEESE (*op. cit.* sect. 45).

right auricle. The transverse branch in the neck (*d*) is not half the size of either jugular vein. It crosses over the commencement of the great arteries of the head and neck, and opens into the lateral venous trunks, somewhat below the point of junction of the jugular and subclavian veins of each side. This circumstance (observed also in Professor SHARPEY's preparation) is interesting when considered in relation to the position of the cross branch in the embryo, and to the mode of formation of the right innominate vein.

From opposite the left end of this cross branch, the additional superior cava (*fvlos*) descends upon the aorta, to the front of the root of the left lung, and crossing the corresponding vessels, reaches the side of the left auricle immediately behind the appendix; then turning backwards under the lowermost pulmonary vein in close contact with the auricle, it runs obliquely inwards beneath the base of the heart along the auriculo-ventricular furrow; and finally opens by a wide orifice into the right auricle, to the left of, and somewhat before the inferior cava, *i. e.* in the ordinary situation of the orifice of the coronary sinus.

The azygos vein exists on the right side, and on the left there is a small vein opening into the left cava, about  $1\frac{1}{2}$  inch below the cross branch, and close above the root of the lung: this small vein is a left azygos formed by the persistence of a part of the left cardinal vein: it fulfils the office of the left superior intercostal vein. The azygos and this small left azygos are also seen in Professor SHARPEY's preparation.

From the cross branch down to the root of the lung, *i. e.* outside the pericardium, the left cava is rather narrower than the right. It is placed close beneath the pleura, and supports upon its outer side the left phrenic nerve (14). It rests first upon the left carotid and subclavian arteries, and then on the arch of the aorta. The par vagum (13) descends further back than the vein, and gives off a branch, which accompanies the vessel to the heart. On a level with the upper border of the pulmonary artery, the vein pierces the fibrous layer of the pericardium (11, 11).

Within the pericardium, as may be noticed in all the cases which have been fully described, the left vena cava becomes very much dilated. As it passes from the left pulmonary artery to the root of the subjacent pulmonary vein, it is lodged (*v*) in a tube-like fold of the serous membrane, the analogue of the *vestigial fold*. On the side and back of the left auricle (*lo*), and afterwards along the course of the auriculo-ventricular groove (*s*), the vessel is everywhere covered and bound down by the serous layer of the pericardium, and has muscular walls.

In turning horizontally to the right it receives the coronary vein (*g*), which appears small, and courses rather over the left border of the ventricle than comes from between the ventricle and the auricle. Further on, a posterior (*p*) and then the middle (*m*) cardiac vein enter it from below. The large vessel itself (*o*) occupies the place of the short oblique vein usually found on the back of the left auricle. The lower dilated part of the left vena cava superior (*s*), occupying the place of the coronary sinus, is distinctly muscular, its fibres for the most part being circular and ap-

parently blending with those of both auricles. There are no valves along its course, but the mouth of each of its cardiac branches is guarded with a fine valve, that of the coronary vein being the largest. The wide orifice of the vessel into the right auricle is marked above, below and to the right, by a slight rim, but there is no Thebesian valve, the absence of which, in this and all the other examples of double vena cava superior in which the point is capable of being determined (Nos. 1, 4, 12, 30, 31), suggests a comparison with the fact that it is also absent in those large quadrupeds which have a left vena cava superior or a left azygos venous trunk. The Eustachian valve is small and perforate; its left cornu does not reach the lower border of the fossa ovalis, owing, as it were, to the intervention of the large orifice of the left superior cava. The foramen ovale is quite closed.

The second example (No. 31) of double vena cava superior which I have to mention, occurred in the heart of a child between four and five years of age; in the ventricular portion of which there are some defects. The auricles, however, are perfectly shut off from each other. The lower part only of the left superior cava is present in the preparation, that vessel having been divided opposite the left pulmonary veins: it is very large and muscular, and receives the coronary and one other principal cardiac vein, the orifices of both being provided with valves. The opening of the vessel into the auricle is marked by a sharp border; but, as in other cases, the Thebesian valve is wanting. So, too, is the Eustachian valve.

b. *With transposition*.—There is, so far as I am aware, but one instance on record of the occurrence of double vena cava superior, together with transposition of the viscera. In this case the superadded vein is of course on the right side: a small vena azygos exists on that side, and ends in the right vena cava\*.

## CLASS II. TRANSVERSE BRANCH WANTING.

A failure in the preliminary step of the development of a cross branch in the neck necessarily implies the non-occlusion of either of the lateral primitive veins; for, though two superior cavæ may coexist with the transverse communication in the neck, yet, when the latter is absent, each primitive vein must continue to return the blood from its own side of the upper half of the body.

In such instances the characteristic cross branch of the mammalian venous system is wanting; the condition of the great anterior veins is like that of birds; and there is *no metamorphosis* excepting what is due to changes of size and position in the four simple lateral primitive veins typical of the vertebrate animal. Transposition has not been noticed in connection with this variety.

The best illustration of deficiency of the cross branch occurs in a case (No. 2)†

\* Sir A. COOPER, in Dr. WATSON's paper, Medical Gazette, June 1836, p. 394. The specimen is now in the Museum of the Royal College of Surgeons.

† No. 2. BÖHMER (Observ. Anat. rarior. fasciculi. Præfat. p. xii.). THEUNE (De confluxu trium cavar. in cord. atrio dextro, &c. Halæ, 1763, with a figure. Republished, Amsteld. 1764).

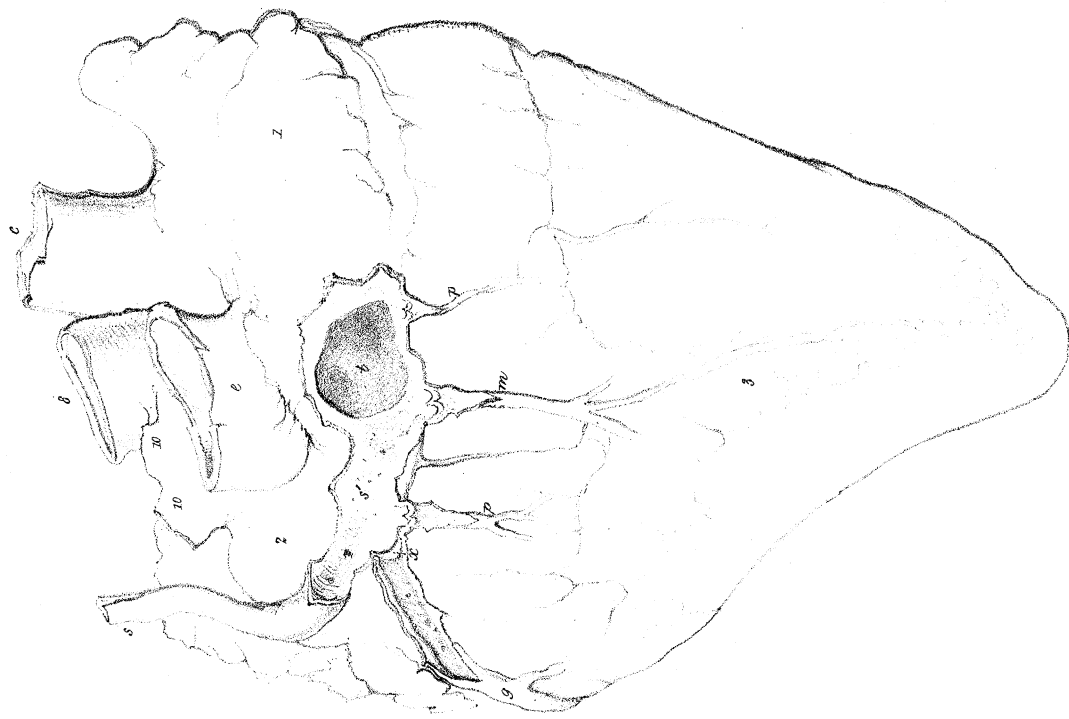


Fig. 1.



reduced  $\frac{2}{3}$  in.

Fig. 2.



natural size.

briefly recorded by BÖHMER, and subsequently clearly described and figured by THEUNE. The subject was a boy, aged 11 years. The vessels of the thorax and neck were injected with wax; and, though numerous small thyroid branches descended to the jugular veins, there was no appearance whatever of a transverse branch across the neck. Besides this, the case is interesting as affording a distinct example of the presence of both azygos veins ending, one in each of the superior cavæ. The right azygos was rather higher than usual; the *left* azygos, a little lower down than the right one, could be followed along the left side of the vertebræ as low as the lumbar veins in the abdomen.

Another specimen of double superior cava in an adult (No. 4)\*, in which the cross branch must be regarded as wanting, has been elaborately described and represented in two figures by ADOLPHE MURRAY. With the exception of this deficiency of the cross branch, and of apparent absence of the left azygos also, the case resembles No. 30. The coronary vein is described as wanting: but it was represented by a branch which, as in case No. 30, turned over the left border of the heart.

The four remaining examples were in malformed fœtuses, carefully dissected by HALLER, by WEESE and by WIRTENSOHN (Nos. 3, 17, 18 and 19)†.

Finally, such extreme cases of malformation as those in which (as in acephalous or almost shapeless fœtuses) the primitive plan of the venous system is altogether abrogated, do not here come under consideration.

## DESCRIPTION OF THE PLATES.

### PLATE I.

Fig. 1. Sketch of the human heart, seen on its left and posterior aspect, together with the great blood-vessels and a piece of the left lung:—reduced one-fifth. The coronary sinus, the great coronary vein, and the other posterior cardiac veins have been slit up. 1. The right auricle. 2. The left auricle. 3. The ventricular portion of the heart. 4. Portion of the root of the left lung. 8. The aorta. 9. The pulmonary artery. 10, 10. The left pulmonary veins. 11, 11. The cut edge of the pericardium. *c.* Vena cava superior. *e.* Vena cava inferior. *g.* Great coronary vein. *m.* Middle cardiac vein. *p, p.* Posterior cardiac veins. *s.* Coronary sinus laid open,

\* MURRAY, AD. (Neue Schwedische Abhandl. aus der Naturlehre, &c., band 2, p. 283, with two plates). He refers to BARTHOLINE, CHESELDEN and HALLER; and also to BÖHMER and THEUNE, whose observation he considers the only one like his own.

† No. 3. HALLER (Descript. Monstr. dissect. i. 1739. Oper. Minora, t. iii. p. 102. 5. Tabul. xv.). The peculiarity in question occurs in the left fœtus only of a double monster. No. 17. WEESE (*op. cit.* sect. 47, p. 30. Tabul. vi. fig. 1). This was a case of Ectopia cordis which had been previously examined by KUESTNER. The left veins *did not join* those of the right side, but descended separately to the heart by a left venous trunk. Nos. 18, 19. WIRTENSOHN, Diss. duor. Monstr. dupl. humanor. Berol. 1825, p. 23.

to show the large valve *x*, at the mouth of the great coronary vein (*g*), and smaller valves at the mouths of the posterior (*p, p*) and middle (*m*) cardiac veins. *t*. Orifice of the coronary sinus into the right auricle, with the Thebesian valve. *o, l, v*. Remains of the left primitive venous trunk above the coronary sinus, consisting of *o*, a small oblique auricular vein; *l*, lines or streaks on the wall of the left auricle; and *v*, a small duplicature of the serous layer of the pericardium, passing between the left pulmonary artery and the subjacent pulmonary vein, which is referred to in subsequent plates as the *vestigial fold of the pericardium*.

Fig. 2. Sketch of the back of the Sheep's heart; the great vessels being cut off short. 1, 2, 3, 8, 10, 10, *c* and *e* refer to the same parts as in fig. 1. *s, s'*. The trunk of the left azygos vein laid open, showing the large valve (*x*) at the entrance of the great coronary vein (*g*), and the smaller valves at the mouths of the veins marked *p, m, p*. The portion of the left azygos vein marked *s'*, is analogous to the coronary sinus in Man, *s*, fig. 1. *t*. Orifice of the left vena azygos, destitute of a Thebesian valve.

## PLATE II.

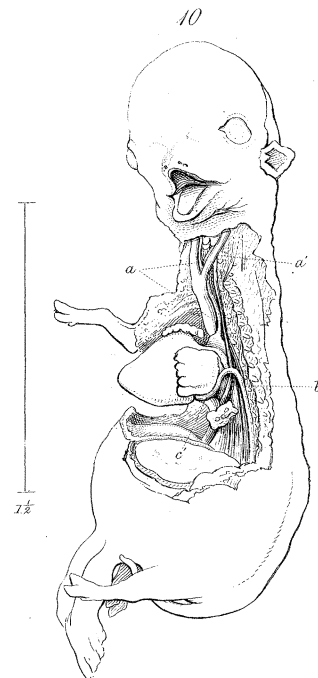
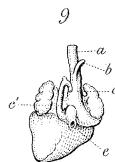
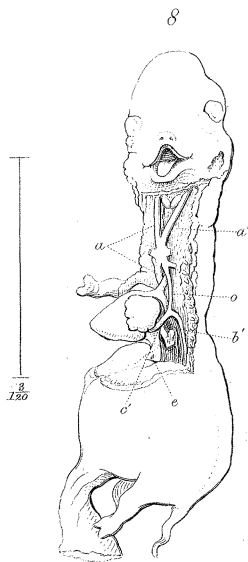
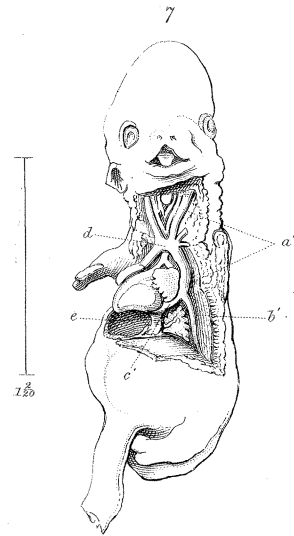
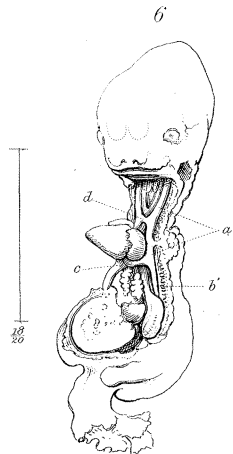
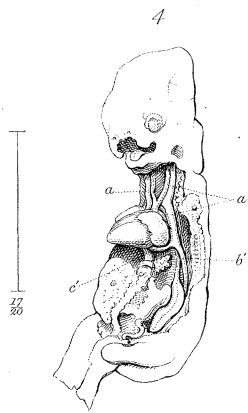
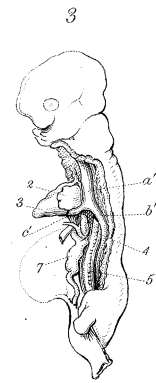
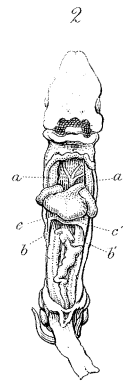
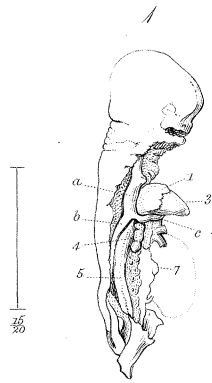
Development of the great anterior veins in the embryo of the Sheep. Each figure is magnified two diameters. Corresponding letters of reference are used in common; viz. *a*. The right, and *a'*, the left primitive jugular vein; *o*, the occluded portion of the left primitive jugular vein. *b*. The right, and *b'*, the left cardinal vein. *c*. The right, and *c'*, the left canal of CUVIER. *d*. The transverse branch across the root of the neck, afterwards the left innominate vein. *e*. The trunk of the future vena cava inferior. 1. The right auricle. 2. The left auricle. 3. The ventricles. 4, 4'. The lungs, right or left. 5, 5'. The Wolffian bodies, right or left. 7. The stomach.

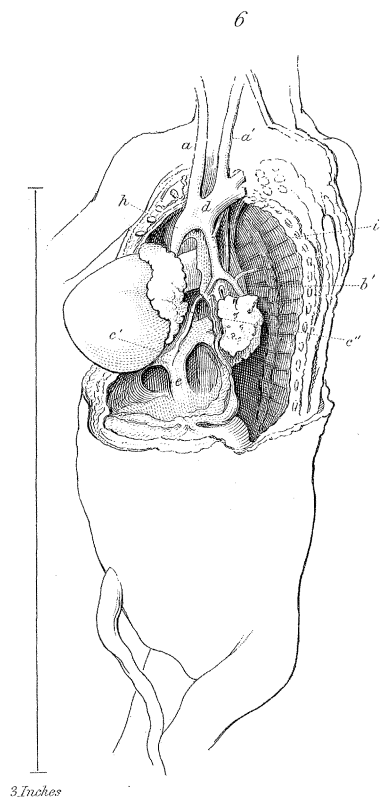
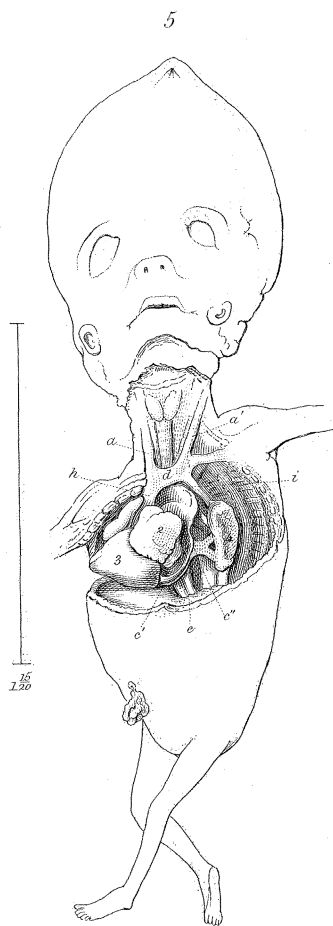
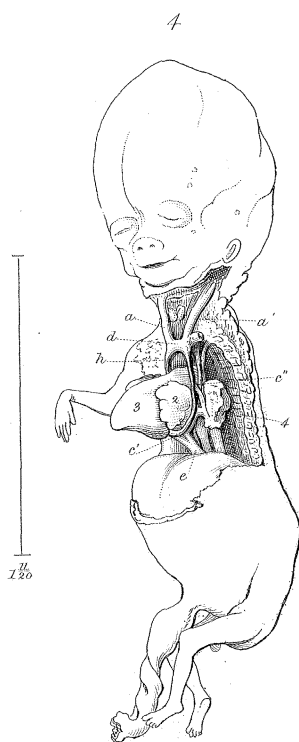
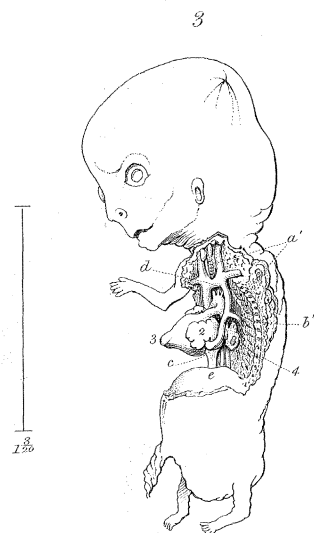
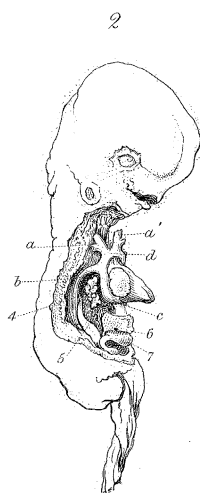
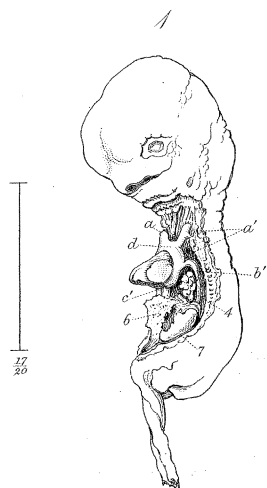
Figs. 1, 2, 3. Lateral and front views of an embryo,  $\frac{1}{20}$ ths of an inch long. The great anterior veins are symmetrical, and consist of four lateral trunks, viz. two jugular and two cardinal veins, ending in the two Cuvierian canals. The jugular veins are short and vertical; the cross branch is wanting, but two little points are seen projecting from the inner side of the jugular veins where this transverse vessel is to appear. The dotted lines in figs. 1 and 3 indicate the outline of the liver, which has been removed.

Fig. 4. Embryo,  $\frac{1}{20}$ ths of an inch long. The jugular veins elongated, and beginning to approach each other opposite the place of the future transverse branch, which could not be traced quite across the neck. The cardinal veins are smaller, owing to the wasting of the Wolffian bodies.

Fig. 5. Heart of an embryo, 1 inch long. The cross branch distinct, consisting of a fine vessel, which is wider at each end than in the middle.

Fig. 6. Embryo,  $\frac{1}{20}$ ths of an inch, and fig. 7, embryo,  $\frac{2}{20}$ ths of an inch long. The jugular veins have become more closely approximated at the root of the neck. The





cross branch is shorter and wider. The lower part of each primitive jugular, below the cross branch, inclines downwards and outwards, lying upon the pericardium. The left cardinal vein is still further reduced in size, but no occlusion has yet taken place.

Fig. 8. Embryo, 1 inch and  $\frac{3}{20}$ ths long. In this embryo, and in embryo fig. 10, most part of the left lung has been cut away. The lower part of the left primitive jugular, extending from below the cross branch to the junction of the left cardinal vein and left canal of CUVIER, is occluded, and a fine opake cord (*o*) exists in its place. The left cardinal vein and left Cuvierian canal now form the left vena azygos, as in the adult, the intrapericardial portion of which is seen to cross the left pulmonary vessels, and is lodged in a fold of the serous membrane. The cross branch now passes obliquely over to the right side, and forms the left innominate vein, which ends in the lower part of the right jugular, now the vena cava superior.

Fig. 9. Back of the heart of an embryo,  $1\frac{1}{4}$  inch long, to show the differences, in size, length and direction, between the right and left Cuvierian canals, after the partial occlusion of the left jugular. The different heights of the right and left azygos veins are also exhibited.

Fig. 10. Embryo,  $1\frac{1}{2}$  inch in length; it shows the state of the primitive anterior venous trunks after the completion of their metamorphosis, and therefore resembles the adult condition.

### PLATE III.

Development of the great anterior veins in the human embryo. Each figure is magnified two diameters. Corresponding letters of reference are used in all cases, viz. *a*. The right, and *a'*, the left primitive jugular vein. *b*. The right, and *b'*, the left cardinal vein. *c*. The right, and *c'*, the left canal of CUVIER, or its pervious remnants. *c''*. Occluded portion of the left canal of CUVIER. *d*. The transverse branch in the neck, afterwards the left innominate vein. *e*. The vena cava inferior. *h*. The vena cava superior. *i*. Trunk of the left superior intercostal vein. 2. Left auricle. 3. Ventricular portion of the heart. 4. Lung, or part of lung. 5. Wolffian body. 6. Part of the liver. 7. The stomach.

Figs. 1, 2. Left and right lateral view of an embryo,  $\frac{17}{20}$ ths of an inch in length. The cross branch is fully formed and very wide. The cardinal veins have diminished with the wasting of the Wolffian bodies; but no occlusion having taken place, the great lateral venous trunks are still symmetrical. N.B. Embryo damaged before dissection.

Fig. 3. Embryo,  $1\frac{3}{20}$ ths of an inch long. The lower part of the left primitive jugular (below the cross branch) is elongated, and, as well as the left Cuvierian canal, is beginning to shrink.

Fig. 4. Embryo,  $1\frac{11}{20}$ ths of an inch long. The left primitive jugular vein below the

cross branch is entirely occluded, and also the succeeding part of the left Cuvierian canal, the lower end of which, however, remains pervious as a little conical pouch (*c'*) on the back of the left auricle. A fine cord (*c''*) occupies the place of the occluded vessel. The left cardinal vein has disappeared. The cross branch, now oblique in direction, forms the left innominate vein (*d*), which ends in the vena cava superior (*h*).

Fig. 5. Embryo,  $1\frac{1}{2}\frac{5}{10}$ ths of an inch long from vertex to coccyx, and fig. 6, embryo, 3 inches from vertex to coccyx. In these embryos, a portion of the left primitive jugular vein immediately below the cross branch remains open, though reduced in size, and forms the trunk of the left superior intercostal vein (*i*); the succeeding portion is occluded and forms a fine semitransparent cord, which is continuous through the pericardium, with the occluded part of the left canal of CUVIER (*c''*). This latter lies in a fold of the serous membrane in front of the left pulmonary vessels, and descends on the back of the left auricle to the conical pouch (*c'*) above mentioned. The left cardinal vein (*b'*) in fig. 6, relatively very much diminished in size, appears to form a branch of the left superior intercostal vein.

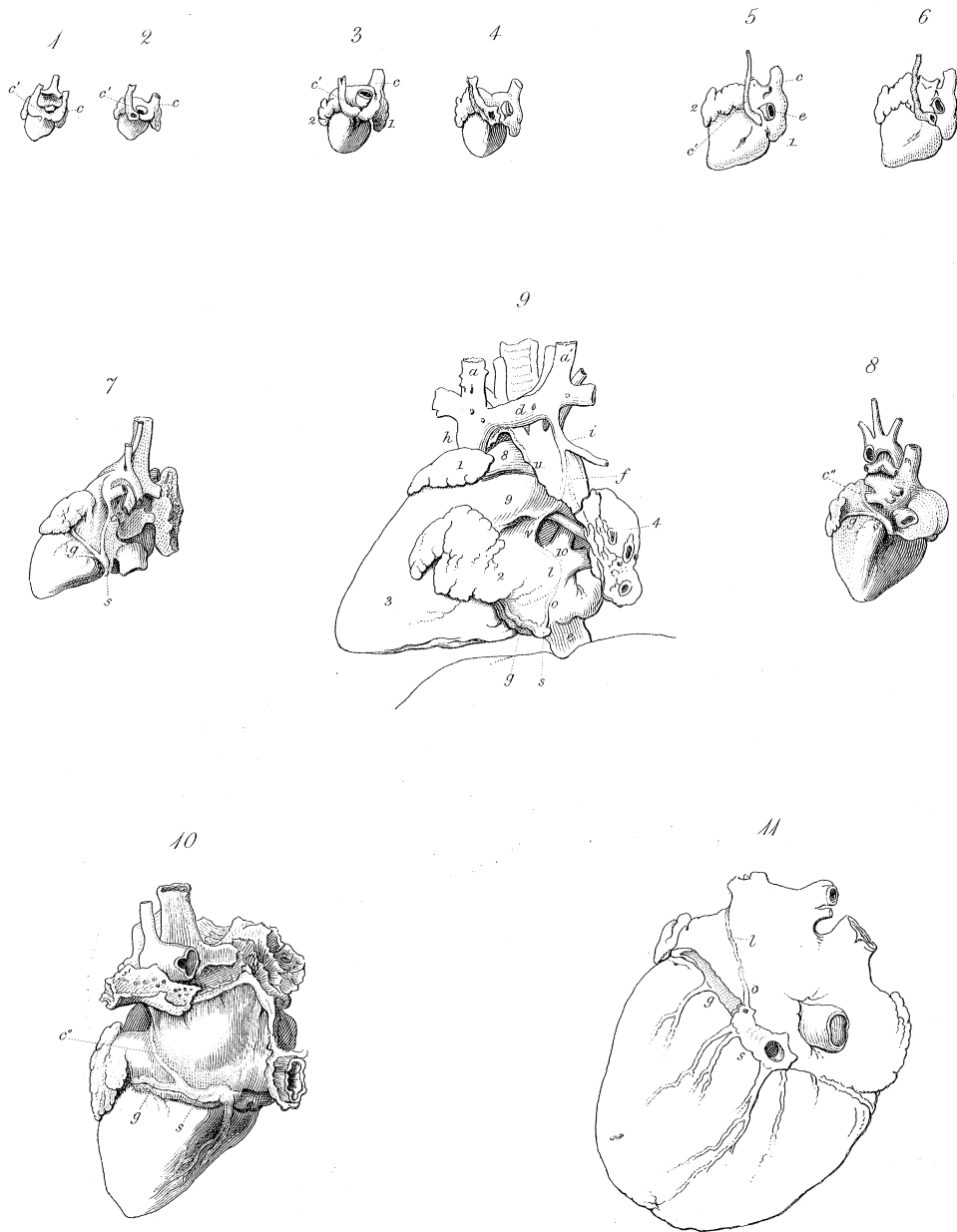
#### PLATE IV.

Several views of the hearts of human embryos to show the gradual alterations in the size, length and direction of the two canals of CUVIER, and the particular metamorphosis of the left canal. Figs. 1 to 6 and figs. 8, 10 and 11 are views of the under surface of the organ. Figs. 7 and 9 are representations of its left side. All the figures, excepting fig. 11, are shown magnified two diameters.

The letters of reference employed in the several figures are as follows. *a*. Right and *a'* left jugular. *c*. Right, and *c'*, left canal of CUVIER. *c''*. Occluded portion of this canal. *d*. Cross branch in the neck, or left innominate vein. *e*. Vena cava inferior. *f v l o s*. Parts occupying the place of the left canal of CUVIER, viz. *f*. Fibrous bands beneath the left pleura outside the pericardium, *v*. Vestigial fold of the pericardium, *l*. Lines or streaks on the back of the left auricles, *o*. Oblique auricular vein, and *s*. Coronary sinus. *g*. Great cardiac or coronary vein. *h*. Vena cava superior. 1. Right, and 2, left auricle. 3. Ventricles. 4. Part of left lung. 8. Aorta. 9. Pulmonary artery. 10. Left pulmonary veins. 11. Cut edge of the pericardium.

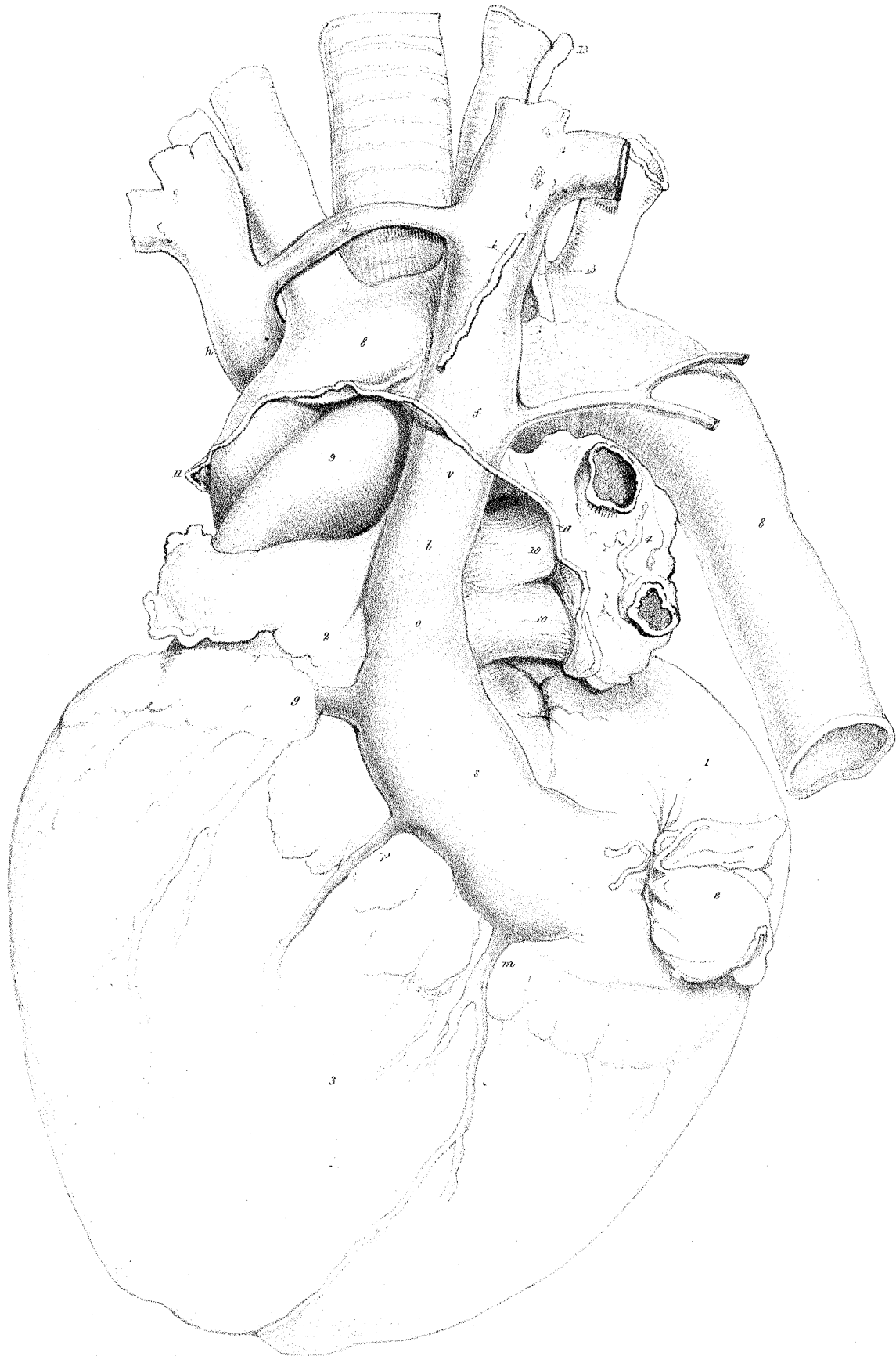
Figs. 1, 2. Heart of an embryo,  $\frac{1}{2}\frac{7}{10}$ ths of an inch long. Figs. 3, 4. Heart of an embryo, 1 inch long. Figs. 5, 6. Heart of an embryo,  $1\frac{6}{10}$ ths of an inch long. In these figures, viz. 1, 3 and 5, the right canal of CUVIER (*c*), is seen progressively to become shorter, wider and more vertical: the left canal (*c'*), which is shown opened in figs. 2, 4 and 6, becomes longer, narrower, and more circuitous in its course to the right auricle.

Fig. 7, left side, and fig. 8, the under surface of the heart of an embryo,  $2\frac{1}{2}$  inches long. The cavities of the heart are filled with hardened blood. The upper occluded part of the left canal of CUVIER (*c''*) is well seen; and also the transformation of its









lower portion into a small oblique vein and the coronary sinus (*s*), into which, at its junction with the oblique vein, the coronary vein (*g*) enters.

Fig. 9. Outline plan carefully constructed from the heart of an embryo, measuring 5 inches from the vertex to the coccyx. The essential stages of the metamorphosis of the left primitive venous trunks are so complete, that the parts now representing it are nearly the same as in the adult condition, viz. the trunk of the left superior intercostal vein (*i*), the vertical fibres beneath the left pleura (*f*), the vestigial fold (*v*), and the lines or streaks (*l*) on the left auricle. The lower persistent portion of the left canal of CUVIER is transformed into a short oblique vein (*o*) and the coronary sinus (*s*), which are only partly seen, and which are joined by the great cardiac or coronary vein (*g*).

Fig. 10. Heart of the same embryo. The lines or streaks (*c''*), the oblique vein, the coronary sinus (*s*) and the coronary vein (*g*) appear almost as in the adult heart.

Fig. 11. Heart of a small foetus, still-born at the full period. The drawing is of the natural dimensions. The metamorphosed parts are easily recognized. The coronary vein (*g*) and sinus (*s*) are slit up, to show the commencing valve at their point of junction, and the place of opening of the oblique vein (*o*), which is continued up into the line or streak (*l*).

#### PLATE V.

Sketch of the under surface and left side of the heart, great blood-vessels, and root of the left lung, from a female aged 19; exhibiting the remains of the left anterior primitive vein, as ordinarily seen in the adult human heart. 1, 2, 3, 4, 8, 9, 10, 10, 11 and *e*, refer to the same parts as in Plate I. fig. 1. 13. The left vagus nerve. *d*. Left innominate vein, formed by the primitive cross branch and part of left primitive jugular. *i*. Trunk of the left superior intercostal vein, formed by the part of the metamorphosed left jugular vein situated immediately below the cross branch in the neck. *f*. Indistinct fibrous bands, mixed with small vessels and nervous cords, shown after removal of the pleura, lying in the track of the previously existing vein, and passing down to the root of the left lung, and thence through the pericardium into the fold marked *v*. *v*. The *vestigial fold* of the pericardium, persisting after the occlusion of the corresponding part of the left canal of CUVIER. *l*. Lines or streaks on the wall of the left auricle, descending from the vestigial fold to a small oblique vein, marked *o*. This oblique vein (*o*) enters the coronary sinus (*s*) close by the valved orifice of the coronary vein (*g*): together with the sinus, it forms the lower persistent pervious portion of the left primitive vein or canal of CUVIER.

#### PLATE VI.

Sketch of the under surface and left side of the heart and great vessels of a man, aged 56 years, in which there is a second superior cava on the left side, constituting

what is termed a case of "double vena cava superior." 1, 2, 3, 4, 8, 9, 10, 11 and *e*, refer to the same parts as in Plate I. fig. 1. 13. The vagus nerve. 14. Portion of the left phrenic nerve resting on the left vena cava superior. *d*. The cross branch at the root of the neck passing across below the place of junction of the subclavian and jugular veins. *h*. Part of the right vena cava superior. *i*. A left superior intercostal vein crossing over the descending aorta and acting as a small left azygos vein. *f*, *v*, *l*, *o* and *s*, are placed on the successive portions of the left vena cava, or persistent left primitive vein, which correspond with the successive remains met with in the ordinary condition, viz. *f*, with the subpleural fibrous bands; *v*, with the vestigial fold between the left pulmonary artery and veins; *l*, with the lines on the back of the left auricle; *o*, with the oblique vein; and *s*, with the coronary sinus. Into this latter there open, *g*, the great coronary vein, *p*, a posterior, and *m*, the middle cardiac vein.