Observations on the heart, and on the peculiarities of the foetus / By James Jeffray.

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OBSERVATIONS

ON THE HEART,

AND ON THE

PECULIARITIES OF THE FŒTUS,

BY

JAMES JEFFRAY, M.D.

PROFESSOR OF ANATOMY IN THE UNIVERSITY OF GLASGOW, ETC.

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M.DCCC.XXXV.

TO

JAMES M'DONNELL, M.D.

BELFAST.

DEAR SIR,

It is now more than half a century since you and I first met, as fellow-students, in the University of Edinburgh, and listened delighted to the Lectures of Cullen and Munro, and Black and Gregory. It says, perhaps, little for either of us, that during all that long time we have published few of the observations which must occasionally have forced themselves on our notice. The difficulty, they say, lies in the first step. In the hope that you will take the second, I have yielded to solicitation, and agreed to publish some of the Lectures of which you inform me you have heard from the young men of your country who have studied at this University. They should have been thrown into the form of an essay; but several of those of this country, who studied here long ago, have intimated a wish that they should be given as the Lectures they heard spoken or read. With that wish I have complied—and hope that you will, as an old friend and fellow-labourer, let the little work go forth under the patronage of your respected name.

I am,

DEAR SIR,

Yours sincerely,

JAMES JEFFRAY.

UNIVERSITY, GLASGOW,
May 7th, 1835.

OBSERVATIONS ON THE HEART

AND THE

PECULIARITIES OF THE FŒTUS.

We have now shown you the heart, and examined with you its different parts, both in the human subject and in several other animals, and explained their action in the usual way. There are, however, several circumstances, especially in the right auricle, which require a more minute and attentive examination.

It is an opinion almost general among anatomists that the venous blood is returned to the right side of the heart alone, and poured into the right auricle at three different points, by the superior and inferior cavæ and the coronary vein. As for the veins of Thebesius, which are said to have been observed terminating in the left side of the heart, I have never met with any of them that attracted attention, till last winter, when, as some of you who were present will recollect, I was much surprised, during the de-

monstration of the right auricle, to find no coronary vein (*fig.* 1, *f.*); and I was still more surprised when, on laying open the left auricle, that vein was seen opening out there, but rather farther up in the auricular cavity than usual. You will also remember that we injected fluids into several of the larger branches of the coronary vein, and that these fluids issued all into the cavity of the left auricle by a large opening (*fig.* 2, *d.*), which proved to be the mouth of the coronary vein, while none of it was seen entering into the right. The subject was a male, and rather advanced in years. What the inconveniences were, if any, which he suffered from this malconformation of heart, cannot now be known, as he was a stranger, and of his history nothing could be collected. As the case was uncommon, we have had drawings taken both of the right and the left auricle, which, as well as the preparation itself, I now shew you. A broad piece of whalebone is introduced into the mouth of the vein, and is distinctly seen in the preparation, and imitated in the drawing (*fig.* 2.).

Another circumstance, with regard to which there seems to be ground for some difference of opinion, is, that although the currents of the two venæ cavæ do not enter the auricle directly opposite to one another, but obliquely, and hold on together toward the left side of the auricle; yet, if you examine a little more minutely any of these injected hearts, you will see that while the current of the superior cava (*fig.* 4, *b.*),

enters from above downwards, and to the left, it also is directed forward, and comes into contact with the posterior surface of the anterior wall; while that of the inferior cava (*fig.* 4, *a.*) enters from below upwards, and to the left also, and holds on upward in contact with the anterior surface of the posterior wall; so that, although the posterior surface of the current of the superior cava comes in contact with the anterior surface of that of the inferior cava, and the parts of the two currents which thus come into contact, go on to the left together, the strength of the two currents must pass one another.

"What shall we say," says Mr. John Bell, "of Anatomists, who, in the narrow circle of the auricle, conceive two currents to cross one another, as the arrows by which such currents are usually represented in a map?" I cannot tell, but here are the preparations, far surer guides than drawings or reasonings, and I leave you to judge for yourselves.

There is some dubiety also, with regard to the manner in which the heart itself is supplied with blood, which involves the function of the sigmoid valves, and the arterial sinuses. The arteries which go to other viscera, the liver for instance, and the kidney, &c., plunge into them, and then ramify outwards toward the surface. But the coronary arteries run along in the deep tendinous grooves between the auricles and the ventricles. This tendinous ring in the left side of the heart, for instance, gives origin

or fixture at its lower border, to the muscular fibres that pass downwards from it, and form the left ventricle; while another set go off from its upper border, to form the auricle, leaving a considerable sunk space, two or three lines in breadth, between, from which no muscular fibres rise. In this fossa the coronary artery lies secure, being defended on the one side by the thick upper edge of the ventricle, and by the under edge of the auricle on the other. As the artery proceeds onwards, following the curve of the groove, it gives out branches downwards, from its under side to the ventricle, and similar branches upward to the auricle. These divide in the substance of both auricle and ventricle to great minuteness.

The veins, in almost every other part of the body, decrease like the arteries, as they proceed from the heart; but their currents run contrary to that of the arteries. But in the heart, the currents of the large branches of the coronary vein, which lie alongside of the coronary arteries, and fill up the greater part of the groove, run in the same direction with that of the arteries; so that by the time the two arteries have got round, in their grooves, to the posterior side of the heart, where, greatly diminished in size, they meet and send down their last branches towards the apex, the veins that have accompanied them, increased greatly in size, having received, as they came along, all the branches which both ventricles and

auricles had to give, unite and form a short trunk, that has been called the coronary sinus ; which, after runing a little way, till beyond the edge of the septum, penetrates obliquely to the right, through the wall of the auricle, into which, at its inferior left corner, it pours its contents. It might have entered, and had it been a vein any where else, it would have been made to enter, nearly where the coronary arteries had come to touch the heart, and probably between the two, had it not been, that in travelling to that point, it would have been increasing as it went, while the artery was already there, so large as almost to fill the groove, so that it must have stood out a bump, that would have been unprotected. As matters are ordered, the vein is largest where the artery is least, whereby there is room in the groove for both, and all chance of injury is avoided (*vide fig.* 4.).

It should also be observed that the trunk of the vein, lying over the artery, between the right auricle and ventricle, is less than that of the left side; probably because many of the branches, instead of coalescing to form one large vein, terminate directly in the right auricle and ventricle.

But, though the trunks of the coronary arteries and vein be thus protected, their branches, in the substance of the ventricles and auricles, must suffer compression, when these are in systole or contraction; and as the auricle is in diastole when the ventricle is

in systole, blood will pass up freely into the substance of the auricle, when the ventricle is in contraction, and as freely down into the ventricle, when the auricle is in contraction ; so that although each of them receives blood, only during half the time of the heart's beat, the coronary trunks must be receiving blood constantly from the aorta ; else they could not be prepared to furnish a regular and alternate supply. But how can that be done, if, as some say, the mouths of the coronary ateries are uncovered and open, only during the expansion or diastole of the ventricles ; when the blood is attempting to get back into the ventricle, but is prevented by the sigmoid valves? (*vide fig.* 5.) Then, indeed, the mouths, it is said, of the coronaries being uncovered and patent, the blood may, and does enter freely ; but, during the systole of the ventricle, when the blood is rushing out from the ventricle, and pressing the valves aside, and applying them close over the mouths of the coronary arteries, in the sinuses, no blood can be allowed to enter.

With regard to this opinion, however, there is reason to doubt. Senac has been at the pains to collect the opinions of the most eminent of those who have written on the subject, and states, both from the observations of some of them and his own, that though, in general, the valves cover the sinuses, yet the mouths of the coronary arteries are not always in the sinuses, but sometimes

one of them, sometimes both, are beyond them. It should also be remembered, that during the contraction of the ventricle, the whole root or beginning of the aorta, as well as the sinuses, is, at that time, filled with blood issuing from the contracting ventricle, and that the valve, in yielding to the pressure of the blood issuing from the ventricle, must, as it recedes towards the sinus, carry before it a column or mass of blood, equal to what the sinus can contain; and, it is as evident, that as this quantity is more than the coronary arteries can immediately admit, a part of it must be forced out of the sinus into the calibre of the aorta, by the pressure made on the valve, by the blood issuing from the ventricle; by which means a communication comes to be instituted between the sinus and the calibre of the aorta.

That this may be the more easily effected, all that part of the valve which during the diastole of the ventricle is stretched, so that, as Lower has said, it is like a sail filled with the wind, is, during the contraction of the ventricle, acted on by two forces, namely, the pressure of the blood issuing from the ventricle; and the resistance of the blood in the sinus; so that it is then like a sail shivering in the wind; and that part of it, which is above the cornua, falls down towards the rest in folds or gathers (*fig. 5. d. d. d.*), leaving an opening through which what blood is in the sinus, and which the coronary arteries

cannot receive, may get out; while all the time the mouths of the coronary arteries are left uncovered, and ready to receive what blood the pressure of the valves can force them to take in.

It may, however, be said, that this cannot be the use of the sinuses; for there are but two coronary arteries, and yet there are three sinuses; and the pulmonary artery is furnished with a sinus for each of its three semilunar valves, as large and complete as those of the aorta, while from these sinuses no coronary vessels proceed. This is true: but it only proves, that there must be some other use of the sinuses, than that of rendering the supply of blood to the heart, as abundant and sure, during the systole of the ventricle, as it is during its diastole;—and that there is such another, and a most important use, begins to appear, when we reflect on the risk that would have arisen, had there been no sinuses; or had there been no blood behind the valves; or had the valves, during the systole of the arteries, been pressed as firmly against the wall of the artery, as the boy's leathern sucker against the stone, so that the valve would not have risen readily and correctly, when required. This risk, however, is completely prevented, by the blood in the sinuses, behind the valves, which not only prevents the valves from adhering to the inner side of, nay, prevents them from getting near to, the walls of the sinuses, but forces the triangular lappet-like part of the valves that is above the cornua—*i. e.* above the

body of the valve, to yield or bend forward, whereby the valve is put in the way of, and is prepared to be caught by the blood, attempting to get back into the ventricle, as soon as the diastole of the ventricle begins, when it is immediately laid athwart the calibre of the artery, by the refluent tide.

These things being considered, we now can understand, in the first place, why the trunks of the coronary arteries run along so far in the groove, between the auricles and ventricles. They cannot be compressed there, either by auricle or ventricle; and they are, of course, ready to send their contents up into the vessels of the auricles, when these are in diastole, and downwards into the vessels of the ventricles, the moment these begin to expand, and allow their vessels to be patent and free. We see, in the second place, that in order to supply these two sets of vessels regularly and alternately, with the due quantity of blood, the uncompressed trunks of these coronary arteries must always be full,—and that they may be always full, their mouths must not be, and are not covered or closed up, by the semilunar valves, either during the systole or diastole of the aorta, or pulmonary artery,—and, in the third place, we are led to believe that the blood in the sinuses, compressed by the receding valves, issues out into the area of the artery, carrying the upper part of the valves before it, so that the blood returning, no matter whether by the muscular or elastic contraction of the

artery, or by the elastic expansion and suction power of the ventricle, can easily and certainly get behind them, and instantaneously throw them down, so as effectually to prevent the return of the blood from the arteries into the ventricles.

Before leaving this part of the subject, which, after all that has been said, I am afraid you will find to be, as the use of the arterial sinuses always has been, obscure, I may point out to you an appearance in the structure of the walls of these sinuses, particularly in the heart of the ox, which, to me at least, was unexpected, and still is surprising. The wall of the aorta and pulmonary artery, from the upper edge of their embossments or sinuses, down to their origin in the tendinous brim of the ventricular foramen, turns gradually thinner, more limber, and less elastic, than anywhere else (*fig. 5, e. e. e.*); yet, this is the very part of these arteries that we would expect to be thickest, and strongest, and most powerfully muscular, or elastic; for, it has to withstand and endure the unimpaired impulse of the blood, issuing from the powerfully contracting ventricle.

I thought, at one time, that this part of the tube was formed of the external and internal coats only, and that the middle coat, the elastic, the muscular, which elsewhere, is by far the thickest and the strongest, was awanting: but, on more careful examination, the external and internal coats were found to be exceedingly thin, and devoid of either muscular

or elastic power; but the middle coat was, like that elsewhere, though, especially near the ventricle, about one-third only of the usual thickness. Having ascertained the fact, I frankly confessed at Lecture, that so far as I had considered the matter, I did not see a satisfactory reason, for this unexpected diminution of the thickness and strength of the parts.

The following circumstances, however, should not be overlooked. Nature seldom, if ever, wastes either matter or power. Now, the semilunar valves, though they be not actual parts of the walls of the artery, are most assuredly helps to the walls of the sinuses: for, the force of the ventricle comes first against them, and the resistance they give must be great, for they are of considerable thickness, and their structure approaches to that of fibro-cartilage. The blood issuing from the ventricle must carry them before it; therefore, by how much resistance they give, may the thickness and strength of the walls of the sinuses be lessened. And when it is considered, that the valves are rooted in the tendinous brims of the foramina arterio-ventricularia below, and to the wall of the artery, all the way up to the tips of their cornua, and that they become broader, and of course more moveable, or less capable of resistance above than below, it becomes almost evident, that the walls of the sinuses may be allowed to decrease in thickness and strength, as they descend. But the subject is too new to me, and requires more patient investigation.

Tubercle of Lower.—This tubercle has given rise to much controversy among Anatomists, in which, I do not think Lower has been altogether well used; at the same time, it must be confessed, that some of his descriptions seem rather to be taken from the brute, than from the human subject. His words are, when translated literally, as follow: "Before the very threshold of the auricle, that is to say, where the vena cava ascendens, meeting with the cava descendens, is about to discharge its contents into the auricle, a certain little swelling or tubercle, (tuberculum quoddam,) raised by the fat underneath, and worthy of being remarked, presents itself; by the intervention of which, the blood descending from the cava superior, is turned aside into the auricle, which otherwise would have fallen into the cava inferior, and have checked and greatly retarded the blood, rising up from it into the heart; and seeing, that in the erect position, the danger from this would have been increased, therefore, the human heart has this tubercle the larger and more projecting, so that if you introduce your finger into either of the trunks of the vena cava, you will scarcely be able to make it reach the other."

It has been objected to this description of Lower, that in the situation where he has placed this tubercle, no globular body is to be found. But this is quarreling with the word which Lower has used to describe this protuberance, or thickening of the part, rather

than with the rising itself. It is obvious that he was at a loss for a word; and, that Vieusenius has not been more fortunate in the terms he has found himself obliged to employ. "There is, (he says,) at the meeting, or between the mouths of the two venæ cavæ, a body, red, elevated into an embossment, irregularly spherical, and composed of fleshy fibres," and as it is situated between the mouths of the two cavæ, like a tongue of land between two seas, he has called it an isthmus. This isthmus obviously is the same with the tubercle of Lower. It has been fashionable to reject both; and Mr. J. Bell has almost sealed their doom, by saying, "at this place, *i. e.* between the mouths of the two venæ cavæ, we should look for the tubercle of Lower, were it not merely an imagination of that anatomist."

We shall see, however, that Lower has fallen into greater mistakes than imagining he had discovered what so many, since his time, have not been able to see. He has said that for reasons, which he gives, "many quadrupeds, such as the dog, the ox, &c. have less need of such a jettee as is found in the human species; yet, in them the tuberculum is not altogether awanting,"—and he gives drawings of the tuberculum, in each; from which it is seen, that in the quadruped, instead of being small, it is very large, as in reality in these animals it always is; while, in the human heart, instead of being so small and depressed as not to be easily recognised, it is, in his drawings, as large

and prominent as in the brute,—which has given room for Senac to suspect that he had transferred to man, what he had seen only in the brute,—and, it must be confessed, his *fig.* 1, in his second plate, which is given as an accurate delineation of the parts in the human heart, to which, however, it has no resemblance, is almost, if not altogether, the same with his *fig.* 2, which is given as that of the brute, and is, indeed, like that of the calf.

I do not see how this dispute is to be settled, but by having recourse to the anatomy of the parts themselves, and in different animals; and while we are looking out for this tubercle of Lower, this isthmus of Vieusenius, we shall endeavour to settle the localities of some other parts, respecting which there has been much controversy, and there still is a difference of opinion.

Having carefully dissected and removed the membranous lining of the right auricle of the human heart, till we come to the border of the fossa ovalis, a plane or layer of muscular fibres are seen, proceeding from about the middle of the posterior part of the brim of the foramen auriculo ventriculare, or foramen venosum of the right auricle, and stretching across, in front of, and forming indeed part of the left side of the auricular septum, they increase in thickness as they go; and are, at their greatest strength and thickness, where they pass immediately above, and form the upper border of the fossa ovalis (*fig.* 1, *c. c.*

fig. 3, *c. c. fig.* 7, *c.*) ; and it is here, between the mouths of the two venæ cavæ, that their increased thickness forms the swelling, that has been called the tubercle of Lower, or isthmus of Vieusenius. In the ox, &c. it rises out from the septum, projecting more than half an inch into the cavity of the auricle, like a ridge or dyke, and is seldom less in thickness than the little finger. In the bear, (*fig.* 17,) it is particularly prominent. What the uses of this very remarkable prominence, in these animals, may be, we shall afterwards see. In the meantime, we may observe, that in the human subject, we see nothing that can be called a tubercle. But there is a distinct and evident thickening of the muscular layer at this place, (*fig.* 1, *c.*) immediately above the fossa ovalis, sufficient to free Lower from the charge of having described what he never saw, but for which, it would seem, he was at a loss for a name. After this flattened band of muscular fibres arrives at the right edge of the septum, they begin to spread out, and turning forward and to the left, they reach the tendinous brim of the auricle, after having formed a considerable part of the inner layer of the expanded anterior wall of the auricle.

I have been in use to call this very remarkable band or set of muscular fibres, (*fig.* 3, *c. c.*) the transversalis, from their direction, or the constrictor, from the effect of their action ; for it is evident, that, as they rise from one side of the brim of the

ventricular foramen, and end in the other (*fig.* 7, *c. c.*), they must, when they contract, urge all the blood, that comes under their control, from behind forwards, from before backwards, and from right to left towards the foramen venosum, or door of the ventricle (*fig.* 1 and 3, *h. h.*).

But what is to bring the blood up from the lower part or bottom of the auricle, or that above down, from the crooked auricula? The constrictor here can have little or no effect, directly; but it is the fixed unyielding point, to which all the other sets of muscular fibres draw. A plane of fibres go off from its upper edge to a tendinous-like sphincter muscle, that rises from the posterior part of the brim of the foramen ventriculare, a little above the last, and, like the last, takes a sweep obliquely outwards but upwards, and, returning along the inner side of the anterior wall of the auricle, is fixed into the anterior part of the brim, nearly opposite to where it began (*fig.* 7, *e. e.*). From its upper edge many of the musculi pectinati rise, and proceed variously connecting themselves with one another, all the way up to the upper end of the auricula. This muscle may be named the sphincter auriculæ.

It is very evident, that the fibres which rise from the transversalis, and pass up to this oblique or sphincter muscle, and which may be named obliqui, must, when they act, draw the sphincter, and all that is connected with it, down towards the transversalis, or

constrictor magnus; and it is as evident, that the musculi pectinati, when they act, must draw down the whole of the auricula, shortening as it proceeds, down towards the sphincter. Whether the sphincter is so powerfully contractile, as the rest of the muscular parts, I cannot say. If it did contract much, it certainly would throw a bar in the way of the blood coming down from the auricula. Be that, however, as it may, it is evident that the blood from the auricula descends, as it were, by two stages: the first part of its journey is effected by the musculi pectinati, which bring it down to the sphincter; and the second is accomplished by the obliqui, which bring it, sphincter and all, down towards the constrictor.

There is a circumstance which here should be mentioned, and I give it the rather, because I have not met with a sufficient and obvious reason for it. It is this: the transversalis, after it has sent up the obliqui to the sphincter auriculæ, passes on, to the right, till it comes near to the mouth of the superior cava. It there sends off a set of fibres, which enter the cava, and give it a red, muscular, sphincter-like lining, for more than an inch up (*fig.* 3, *h. h.*). Now, there would be nothing to surprise us in this, did we see a similar set of fibres sent down to give such a lining to the inferior cava. But this is not the case; yet, as we spend more than the half of our time in the upright posture, whereby the blood in the upper cava gets the benefit of its own weight,

while that in the lower cava has to rise up contrary to gravity, it does appear strange that the two are not put at least on a par; though, doubtless, there must be some good and sufficient reason for it, if we could but find it out.

Having thus seen how the principal muscles, or groups of muscular fibres, that proceed from, or are connected with the transversalis, at its upper edge, are distributed, we may turn to those that go off from it below; and here our attention is at once called to the fossa ovalis, about which there has been no little dispute. Without entering into the discussions that have been raised respecting its shape, which can be made to vary, as the parts are stretched out or crumpled together, it is of more importance that we should determine its place, and the share which the different parts, in its vicinity, have in forming its borders; and among these, we shall find the transversalis to be the chief: for, when this muscle gets so far to the right as to be nearly between the mouths of the venæ cavæ, it sends off a band or flat layer of muscular fibres, which curves gently downwards from what has been called the right columna or border of the fossa (*fig.* 7, *f. fig.* 1 and 3.). This band or cluster of fibres, when it has got nearly half way down, along the border of the fossa, divides into two lesser bands; the outermost of which takes a gentle sweep away from the other (*fig.* 7, *g.*), and, of course, to the right; and having got to the outer

edge of the septum, it turns forward, and to the left, and expanding, loses itself on the inner side of the anterior wall of the auricle. The other half or set of these fibres holds on, forming the border of the fossa (*fig.* 7, *f.*), till, having got nearly to its lower end, it gradually bends to the left, and forms, in part, the lower border of the fossa. The border of the fossa on the right side being thus formed by the band of fibres that come off from the anterior side or surface of the transversalis, and that go to the right; the left border is formed by another set of fibres (*fig.* 7.), rather stronger and broader than the former, that come out from behind the transversalis, but in the contrary direction, and take to the left, instead of the right, and form the left column of the fossa, and dividing like the other, one-half (*k.*) going to the left, and turning forward, and loses itself in the substance of the inner side of the front wall of the auricle; while the other (*i.*) holds on, bending gradually to the right, and forming as they go, the left border of the fossa, they meet, at last, with the fibres from the other side, thus completing the muscular periphery of the fossa.

There seems to be a solicitude to prevent the fossa from giving way at the two ends: as for the two sides, these are sufficiently strengthened by the two fleshly columnæ. The upper end also seems pretty secure, by the one pillar rising from the anterior side of the transversalis, and going to the right; while

the other comes out from behind, and passes to the left. But the columnæ have given off half their strength, by the time they get to the lower end of the fossa—on which account, and to make that end as secure as the one above, a set of transverse fibres are sometimes seen coming out from behind the lower end of the right column, and proceeding directly across, they go in behind the left column, thus binding both together. A similar set of transverse fibres are seen, sometimes a quarter of an inch in breadth, between the columnar border of the lower end of the fossa, and the mouth of the cava inferior; and is all we see analogous to the layer of muscular fibres, in the inside of the mouth of the superior cava; but this is in the heart, the other is in the veins.

It is very obvious, that, as the columnæ of the fossa ovalis are parts of a circle, though large, they must, when they contract, attempt to bring themselves into straight lines; and in doing so, they must approach nearer to one another, and thereby narrow the fossa: at the same time, it is as obvious, that, by shortening themselves, they must bring up the lower part of the auricle, towards the central transversalis, and thereby help to bring the blood under the power of that great constrictor.

Neither can we be at any loss, now, in fixing precisely the place of this fossa; it is not so high up as some would have us believe; far less do the two venæ cavæ meet, as many have supposed. It is not situated

mid-way between the two venæ cavæ. It is considerably farther down—for below, we have the narrow joining of the two columnæ, and the few fibres of the transversalis inferior, between it and the membranous ending or mouth of the inferior cava—while above, not to mention the muscular lining of the superior cava, there is the whole breadth of the transversalis medius or constrictor, and of the fibres that go up from it to meet the cava superior. I mention these circumstances more particularly than it may be thought they deserve; but it will be seen hereafter, that by them an erroneous, but a very fashionable theory must be ultimately judged.

Eustachian Valve.—We come next to a part, in the right auricle, namely, the Eustachian valve, about which there has been, and still is, more diversity of opinion, and more keen, I may almost say bitter discussion, than about all the rest. This valve was discovered by Eustachius, and he has given a drawing of it, though not very well executed. His works were hid by his friends, after his death, to prevent their falling into the hands of Eumanes, who was collecting a library at Pergamus. Long afterwards, they were discovered, but in bad preservation. The valve was recognised by some, but denied by others. The fact is, that frequently it does not exist, especially in old subjects; and even when it does exist, it is with difficulty recognised, if not sought for with caution: for, if the auricle be laid open by an

incision near the left side, it will be cut across, and falling down like the valvulæ conniventes when cut, it will scarcely be seen. But in the young, especially in the fœtus, it is always to be found. In the middle aged it generally begins to give way; the matter, in the interstices of its fibres, is either absorbed, or the impetuous currents of blood force themselves through it, whereby it becomes full of holes (*fig.* 8, *a*. *fig.* 9, *d*. *fig.* 10, *d*.); and at last, in old age, it very frequently disappears altogether. From which, it would appear to be a part that is, somehow or other, essential to the well-being of the very young; of less use to the middle aged; and of no use to the aged at all; which circumstances excite in us a strong desire to get acquainted with it, in all its stages, in the hope that something may cast up in the course of our research, that may explain why all these things should be.

It is chiefly membranous; a few fibres that seem to be muscular, are sometimes seen running along in it longitudinally; but they are few, and weak, and scattered. It is a duplication of the membrane that lines the auricle, as the falx is of the inner membrane of the dura mater; it is broadest at its middle, and becomes gradually narrower towards the two ends, till, at last, it can be no longer seen. That edge of it which is rooted in the heart or septum, is longer than the other, which is free. The upper end of it, (*fig.* 11, *fig.* 13,) or that which rises up along the

septum, bends gradually to the left, or toward the foramen ventriculare; the other, when it has got to the bottom of the auricle, turns forward, and as it ascends on the inner side of the anterior wall of the auricle, it bends to the left also; so that its extremities have been likened to horns; when its free edge is raised, and its body made to project out into the cavity of the auricle, it is like a distended sail, with its back looking toward the fossa ovalis, and its bosom toward the foramen ventriculare.

It has been carelessly described by many as a continuation of the cava inferior, of which they take the membrane that shuts up the bottom of the fossa ovalis as a continuation.

This, however, is a great mistake, and has been the source of other errors. The membranous bottom of the fossa has nothing to do with the inferior cava; the innermost conjoined limbs of the two columnæ, and the fibres of the transversalis inferior, lying between. But granting that the cava did reach up to the fossa, the Eustachian valve, to have been even a fragment of the cava, should not have curved toward the ventricular foramen; its cornua should have been bent toward the cava; instead of doing so, however, the cornua of the valve, and, of course, its bosom, look the other way (*fig.* 11.). Besides, the valve, instead of having any tendency towards the fossa, manifests a decided tendency to

recede from it; following the outer, not the inner border of the left columna, which conducts it away from the cava; and here it should be noticed, that immediately behind its lower and broadest middle part, and, of course, between it and the foramen ventriculare, is the mouth of the coronary vein (*fig.* 3, *f. fig.* 11, *d. fig.* 13, *h.*), from which a smooth gutter or shallow channel, following the bend of the valve, runs upward; and in this, the blood that rushes in from the coronary vein, during the diastole of the auricle, flows upwards, and is directed, not towards the inferior cava, but towards the raised-up back of the tricuspidal valve.

This account of the shape and position of this Eustachian valve, which I am persuaded will, on examination, be found to be correct, settles some disputed points, and sets aside several theories. For instance :—

It has been said, that this valve opposes and turns the current of the inferior cava away from the foramen ventriculare. But why should it do so? The blood is to go through that foramen at last; and the nearer and the more directly it can be allowed to approach it the better. But granting that the blood of the inferior cava did set in directly against this Eustachian valve, which it does not, it would lay it prostrate, and ride over it in its way to the ventricular foramen. After the valve is raised, and its bosom

filled with blood, it may, and does resist any current that may come against it, either from the one side or the other.

Another theory is, that this valve, the Eustachian valve, is folded back by the blood of the superior cava, over the mouth of the cava inferior, and bears up the blood of the upper cava, and prevents it from pressing on the blood of the inferior cava coming in; and as a proof of this, instances are brought from the brute creation, in which, and particularly in the beaver, the valve, it is said, is so large and broad, that when folded back, it covers nearly one-half of the mouth of the inferior cava. This opinion, however, is opposed by many facts.

1st, It is opposed by the position of this valve, in man. The theory takes it for granted that the valve is placed close to the mouth, nay, that it forms part of the mouth of the inferior cava. But you have seen that it rises from the left side of the left columna of the fossa ovalis—and that the whole breadth of the left pillar is interposed between it and the mouth of the inferior cava—so that if it were to be folded back it scarcely could reach the mouth of the vein.

2d, The opinion is opposed also by the size of the valve in man. It is, even when broadest, too narrow to cover the front of the columna and any considerable part of the mouth of the vein.

3d, The opinion is still more seriously opposed by the shape of the valve, and its mode of fixture, which

clearly show, that as its cornua look toward the foramen ventriculare, it cannot, without doing it constraint and injury, be folded back to the mouth of the inferior cava.

4th, It is opposed by another consideration, that seems to have been altogether overlooked, but which unhinges the theory altogether. While the child is in the womb, it lies, in most cases, during the greater part of the time it is there, with its head undermost, whereby the cava superior will be below and the inferior above.

5th, It may, indeed, be said, that in such cases, it may serve to prevent the blood of the under cava from pressing on the blood of the upper; but what are those people to do in whom it has become reticulated; or those in whom it has gone entirely into decay; or how do these animals manage, as the ox for instance, in whom, at no period of their existence, is even the rudiments of it to be seen?

6th, The question, however, is set to rest, by the consideration, that if it really were folded back over the mouth of the inferior cava, by the blood of the superior, it would do harm; for, then it would act like a floor or roof, against which the blood of the under cava would be obliged to impinge, whereby its free and easy entrance into the auricle would be materially obstructed.

Mr. John Bell of late has entered into this almost abandoned controversy, and will have it, that the wall

of this auricle is imperfect; and that the function of the valve is to eke it out, and thereby to help it to force the blood through the ventricular hole. This opinion rests on the idea that the valve is a continuation of the inferior cava; and that all the space that is to the right of it, is vein or sinus venosus; and as the valve does not reach so far forward as to touch the anterior wall, the auricle is imperfect on that side, next the ventricular foramen, and therefore requires the assistance of the valve to help it in urging the blood in the auricle, through the foramen into the ventricle.

I am persuaded that, from what you have seen of the parts, you will not be altogether satisfied with this obscure explanation, ingenious though it be. For, you have seen that the two venæ cavæ do not meet, and never did meet; the transversalis auriculæ or isthmus Vieusenii and the columnæ of the fossa ovalis and the transversalis cavæ inferioris all laying between.

You will also see, that, in reality, the division of the auricle into compartments is merely ideal; in nature it does not exist; the whole forms but one bag; and from the posterior wall of this bag, the Eustachian valve, when present, projects some way forward, into the general cavity, like a low wall or dyke.

You will also perceive, that granting the Eustachian valve to be muscular, of which it seldom manifests any signs, it can have little or no effect in

urging the blood towards the ventricular foramen; for, act as powerfully as it may, the blood would escape from the one side of it to the other; it would mount over it, and escape to the other side.

You will likewise see, that if this valve be not muscular, and powerfully muscular too, it can have no effect in forcing the blood toward the left side, before the auricle begins to contract; for then, it stands forward a rigid obstacle to the blood passing or attempting to pass either way. Neither can it have any effect after the walls of the auricle begin to act; for as soon as the outer wall of the auricle begins to contract, this Eustachian valve must begin to lose its power; for then, its extreme points must approach one another, whereby it will be made to float loose and powerless; nay, you will, from this consideration, clearly see, that as soon as the sluice of the foramen ventriculare begins to open—as soon as the blood in the auricle begins to move toward the ventricle, that moment the Eustachian valve must fall before the tide.

The use of this, the Eustachian valve, then, is neither to edge off the current of the inferior cava from the foramen ventriculare; nor is it to bear up the blood of the cava superior; nor is it to eke out the auricle, which is not imperfect; neither does it urge the blood of either cava toward the ventricular hole.

What, then, you will naturally say, can be the use

of this fugacious valve? Why does it decay as we advance in life? Why is it, in many cases, broken into shreds, and at that period of our existence, too, when we should think it would be most needed? Why, in old age, is scarcely a vestige of it to be seen? and why, in the fœtus, is it never awanting?

In attempting to answer these, which are hard questions, I have, from experience, found that it was best to begin with the uses of the valve in the adult, when it happens to have withstood (as in *figs.* 11 and 13) the causes which, so generally, and even in early life, occasion its decay; and of these, I think, the following are clear and distinct and obvious:—

1st, You have seen the situation of the coronary vein. It enters at the left side of the bottom of the right auricle, immediately behind and between the broadest part of the Eustachian valve, and the foramen ventriculare: and the direction of its current is obliquely upward, from left to right, across the cavity of the auricle (*vide fig.* 3, *f.*).

Now recollect, that, in the first place, the current of the cava superior enters from above obliquely downward, forward, and to the left, and impinges against the tricuspidal valve; which, during the diastole or filling of the auricle, shuts up the foramen ventriculare; and that it must, from the very direction in which it enters, be deflected downwards, and whirling along the bottom of the cavity of the auricle, where the coronary vein enters, it would, by the mo-

mentum of its impetus, brushing along the mouth of the coronary vein, and pressing down its valve, over its mouth, prevent the blood which that vein brings, from getting in—were it not that the Eustachian valve is raised, by the very first gush of blood from the coronary vein, and stands in the way and opposes the passage of the deflected blood of the upper cava, and by checking its career, and bringing it to stagnation, over the mouth of the coronary vein, allows the current of that vein to enter, and mingle itself, as it were unperceived, among the blood of the superior cava now brought to rest.

2dly, We likewise see, that were it not that the Eustachian valve thus rises and resists the current of the superior cava, the blood of that vein whirling along in the bottom of the cavity of the auricle, would impinge against the current of the under cava, and taking it as it were in flank, would break its momentum, and prevent it from entering with all its natural and unimpaired speed.

But you will, and very properly say, surely these, even these uses of this valve, cannot be very important, since, in grown-up people, the valve becomes, in general, reticulated, and lets the blood of the upper cava through; and in the aged it decays, and is absorbed, or is entirely carried away. Why, all that must be granted. But, while the valve exists, and exists entire, these are the functions which, from its size, and shape, and structure, and place, it is

fitted to perform. What the inconveniences are which are suffered, when by accident it is torn, or by age it decays, remain as yet to be ascertained by experience and observation; which leads us to wish to be acquainted with the seemingly more essential services it performs to the fœtus in utero; for there it is never absent, and this leads us at once in among the peculiarities of the fœtal circulation, a subject more difficult than the one we now leave, and to the full as curious and interesting.

Peculiarities of the Circulation in the Fœtus.— The first peculiarity, or organ subservient to the circulation of the fœtus, which I shall mention, is the after-birth or placenta. It is a substance that is external to the fœtus, and adheres to the inner surface of the mother's womb. But it is an organ that belongs rather to the fœtus, than to the mother; for, before impregnation, it is never found in the uterus; it increases in size as the fœtus grows; and, after the child is born, it is separated from the womb, and expelled. Through this organ, a great part of the blood of the fœtus circulates; for, two large arteries are sent to it from the fœtus, which seem to be the continuation of the hypogastrics, rather than branches. They ramify throughout its substance, under the name of the umbilical arteries.

2dly, From this organ, the placenta, a vein (*fig.* 12, *c.*) formed by the union of many branches, takes its course toward the fœtus. It is large and capa-

cious. It enters into the abdomen of the fœtus, by the umbilical hole or navel; it then turns suddenly upwards, and leaving the parietes of the fœtal abdomen, but enclosed in a duplicature of the peritoneum, it slips in behind the lower edge of the liver, at that part where the liver is divided, by a fissure, into its two great lobes. From thence, it continues its way upwards, till it arrives at the protuberance called the lobe of Spigelius, where it enters the liver, and is distributed in the following way.

In the first place, it sends some branches into the substance of the liver itself, which branches ramify there like the hepatic artery, but with this difference, that the branches (*fig.* 12, *d. d. d.*) which the vein sends to the left lobe, are larger compared to the general size of the liver, and more numerous than those which it sends to the right (*fig.* 12, *e.*).

In the next place, it sends a large branch (*f.*) to the vena porta (*m.*), or great vein that collects the blood from all the chylopoietic viscera; which great vein advancing to the liver, enters into it, near the place where the umbilical vein goes in; after which it divides into innumerable branches, which ramify, artery-like, throughout the whole substance of that large viscus—and, of course, the blood of this branch of the umbilical vein that enters the trunk of the vena porta, is distributed throughout the liver, to every part to which the branches of the vena porta are sent.

Lastly, The umbilical vein having given off these branches, holds on its course, and terminates in one of the hepatic veins, just before that vein joins the vena cava, which immediately thereafter enters the right auricle of the heart.

Here, then, we have this vein, the umbilical vein, dividing and terminating in the fœtus, in three different ways.—1st, In the liver direct, like the hepatic artery; 2dly, in the liver, through the medium of the vena porta, like a ventral vein; and, lastly, in the vena cava, like an ordinary vein. This last branch (*fig.* 12, *g.*) has long been known, under the name of the canalis communicans, or ductus venosus. But when we look for this vein, this umbilical vein, in the adult, it is not to be found. In its stead, we see a round, hard, cord-like ligament, which can be traced along the inferior border of the suspensary ligament, in behind the liver, and ending where the umbilical vein entered. This circumstance, therefore, that the umbilical vein shrinks, and becomes impervious, and is converted into a ligament, after birth, while, in the fœtus, it is patent, forms another of the fœtal peculiarities, that stands prominently forward to notice.

3dly, If we now cast our eye on the liver of the fœtus, and compare it with that of the adult, we see that it is much larger than that of the adult, the size of the subjects being considered; and, which is still more remarkable, while the right lobe of the adult

liver is out of all proportion larger than the left, the left lobe, in the fœtus, is so large as to bear to be contrasted with the right.

4thly, In the auricular septum of the fœtal heart, there is a large hole, called the foramen ovale (*fig.* 15); and in the left side of that septum, there is a still larger valve, which more than covers that foramen. In the adult, there is no hole in the septum, between the auricles; on the contrary, we find that the valve, seen in the cavity of the left auricle, in the fœtus, is closely applied to the foramen of the septum of the adult, and has become agglutinated to the wall of the auricle, all round the edges of the foramen; so that when you look into the left auricle, all on that side is seen to be smooth, a little bumpiness only, immediately above where the foramen used to be, excepted. But when we look into the right auricle, a little after birth, on cutting it open on its anterior, or rather its right side, from the vena cava inferior up to the cava superior, we see a deep hollow, well known by the name of the fossa ovalis, with which you are now pretty well acquainted. This fossa is precisely in the place, and is exactly of the dimensions of what was foramen ovale. When we examine it more minutely, we find that its edges are formed by the fleshy parts of the septum, generally called the pillars, the columnæ of the fossa ovalis, and that its bottom is membranous. When you press, in the right auricle, against this membranous

bottom with your finger, and turn your eye to the other side of the septum, you find that you are pushing the now adhering valve of the foramen toward the cavity of the left auricle. In other words, you see that though the valve has overspread the edges of the foramen, on that side next the left auricle, and has actually grown to the septum, shutting up the foramen, so as to prevent any communication between the right and left auricles, yet the fleshy part of the septum, forming the edges of the foramen, have not extended themselves; and because they have not done so, while the valve has adhered, there is a deep fossa in the septum, visible when you examine it on the side next the right auricle, for the membranous lining of the right auricle has been folded in over the edge of the foramen; while on the other side, that next the left auricle, the septum is either altogether smooth, or but gently protuberant, immediately above and for a little way down, along the edges of the former oval hole. So long as this aperture, this foramen ovale, is open, as in the fœtus it always is, there is a free communication, and a regular intercourse between the cavities of the two auricles; whereas, in the adult, no such communication can be found. It is true, that, in some instances, the valve has not adhered completely to the wall of the auricle, so that a probe or a hog's bristle may be passed through from the one side to the other; and in not a few instances, the passage has been found to be as

free and open in the adult as in the fœtus; yet even then, however improbable it may seem, we shall afterwards see that, in the adult, no intercourse is allowed to take place.

5thly, The lungs of the adult, even in their collapsed state, fill a larger space in the cavity of the thorax, than is occupied by those of the fœtus, the size of the different subjects being considered. This is a circumstance that has attracted due notice: for as the child in utero does not respire, there is no atmospheric air in its lungs; and when a piece of such lungs is thrown into water, it sinks; but the lungs of an animal that has respired swim; for the air that has been taken in, during respiration, never can be got altogether out again.

This unexpanded state of the fœtal lungs is not only a peculiarity of itself, but is the cause, we shall find, of almost all the rest; and on that account requires our particular attention.

6thly, Another peculiarity in the structure of the parts subservient to the circulation in the fœtus, is, that although the pulmonary artery of the fœtus be as large, in proportion to the size of the subject, as that of the adult, yet the two branches into which that artery divides, one of which goes to the right lung and the other to the left, are extremely small. They are neither proportioned to those in the adult, nor are they like the continuation of the pulmonary artery, from which they spring. Whereas, in the

adult, the pulmonary artery and its two branches bear a very exact proportion to one another: they being able to receive, and do no more than receive what the pulmonary artery brings.

7thly, The pulmonary artery, in the adult, divides into two branches, whereas that in the fœtus divides into three—and which is more remarkable still, the two which go to the lungs, and are the true and only branches that carry the blood from the right side of the heart to the lungs, are small; the third, which does not go to the lungs at all, but passes backward and a little to the left, till it meets with and ends in the aorta descendens, immediately below that part which is called the arch, and, of course, after the vessels have been sent off to the head, is as large, if not more so, than both the pulmonary branches put together.

This large third branch enters the aorta obliquely and in the direction of the current of the arterial blood, and the copious stream of blood which it conveys joins and flows along with that of the aorta descendens, so that by it the left side of the fœtal heart may be said to communicate with the right, through this branch of the pulmonary artery, as the right was seen to communicate with the left through the foramen ovale. It has been called the canalis or ductus arteriosus. Like the umbilical vein, it becomes impervious, soon after birth, and is converted into a ligament, which ever afterward during life seems

to serve no other purpose than to tie the trunks of the pulmonary artery and of the aorta together, and to retain them in their relative places. Like the umbilical vein, also, it is said to have remained patent sometimes in the adult. Such cases, however, are rare indeed. In general, its cavity is found to be completely obliterated in the adult, and nothing of it can be found but a shrunk, hard, ligamentous chord.

8thly, When we compare the arteries that go up to the head of the fœtus, with those of the adult, we find them to be somewhat larger, the relative size of the subjects considered; and we find the head of the fœtus, when compared with that of its body, to be much larger than that of the adult.

9thly, The fœtal aorta, soon after it has given off the arteries to the head and upper extremities, increases suddenly in size, having been joined by the ductus arteriosus. The adult aorta becomes suddenly considerably smaller.

10thly, When we compare the arteries which go off from the aorta to the viscera of the abdomen, in the fœtus, with the same arteries in the adult, we find them to be considerably smaller, in proportion to the size of the subject, than they are in the adult, which, considering the suddenly increased size of the aorta, is somewhat surprising.

11thly, When we compare the arteries which, in the fœtus, are sent to the cavity of the pelvis, to the parts of generation, to the hips and lower extremities,

in general, with the same arteries in the adult, we find that they are out of all proportion small.

12thly, But when we fix our attention on the aorta of the fœtus, near the inferior part of the spine, where it divides into the two great branches called the iliac arteries, and carry our eye along these two vessels, we not only observe them giving off the ilio-lumbalis to the psoas and iliac muscles, but the hypogastric or internal iliacs, as usual, which dipping down into the pelvis, send off the glutæi to the hips, the ischiadica to the back part of the thigh, the pudic to the parts of generation, and the obturatrix to the upper and inside of the thigh, all of which are exceedingly small; but we see these hypogastrics proceeding onwards, apparently not much diminished in size, and, rising up by the side of the bladder, they reach the parietes of the abdomen, a little above the symphysis of the pubes. Continuing their course upward, and approaching nearer to the mesial line, as they advance, they come into contact, but do not anastomose or coalesce, at the umbilicus, or hole in the parietes of the abdomen, through which the umbilical vein enters. Through this foramen they pass, and twisting round the umbilical vein, like the strands in a rope, and surrounded by a soft and gristly kind of jelly, and enclosed in a covering of one if not more lamellæ of the fœtal skin, they reach the placenta or after-birth, by which the ovum, containing the fœtus, adheres to the inner side of the

mother's womb. They are the well-known umbilical arteries—they exist constantly in the fœtus. In the adult they are not to be found. In their stead, we see two ligaments or solid round cords, which can be traced from the umbilicus along the inner surface of the wall of the abdomen, and down along the sides of the bladder, to the hypogastric arteries, in which they end. Like the umbilical vein and ductus arteriosus, they sometimes continue pervious for some way from the hypogastric arteries; it is even said that they have remained pervious till late in life, and have poured forth blood. But these are rare cases. In a very short time after birth, they usually are converted into ligaments.

13thly, The 13th or last peculiarity is, that the blood in the umbilical arteries, that which comes from the left side of the heart of the fœtus, and flows along the aorta, and is arterial in the adult, is venous in the fœtus; while that in the umbilical vein is arterial. This, which is the most remarkable and the most unexpected of all the peculiarities, we shall find to be a beautiful example of the facility with which nature can overcome difficulties that seem to be insurmountable.

Such are what have been usually called the peculiarities of the fœtal circulation. They have long attracted much attention: and now that they have passed in review before us, that we might recognise and acknowledge them, they challenge a more

particular examination; that we may see the necessity for them, and, if possible, understand their use. Of one thing we may be certain, that whether we be able to see their use or not, they are not there in vain; nay, we may be *a priori* assured, that there is not one of them that is not only useful, but absolutely necessary.

The circumstance which, at first sight, seems to be the most unaccountable, is, that though the fœtus in utero neither eats nor drinks, nor respires, and is in a situation where its powers of generating either heat or cold are not needed, yet the organs of its circulation seem to be more numerous, and more complicated in their structure, than those of the adult. It may, however, now be mentioned, that when these peculiarities shall have been examined and understood, the whole will be seen to be a most beautiful and wonderful display of the wisdom and the foresight and the facility with which nature adapts the means to the end—for by the time we have done with this subject, it will, I trust, appear—1stly, that all these peculiarities are absolutely necessary, and so long as the fœtus remains in the uterus, could not be dispensed with; 2dly, that they are admirably and simply adapted to the purposes they are intended to serve; and, 3dly, that, after birth, they are no longer necessary, and being no longer required, they are either removed altogether, or converted to other

purposes, which, in the new state of the animated machine, are as useful as the old.

The first peculiarity noticed was the temporary organ, the placenta. And here I may premise, that as the functions of this remarkable organ are intimately connected with respiration, and cannot well be understood, at least by the beginner, till that subject has been before us, I would wish to decline saying more now, than that the placenta is an organ in which the venous blood of the fœtus is arterialised; or, it is an organ through which the blood of the fœtus passes, venous, to the mother, and is returned to the child arterial; and as this blood, whether arterialised in the placenta or in the mother, is conveyed from the placenta by the umbilical vein, the circumstance that the blood in the umbilical vein is arterial, is the point from which we may set out, to follow it in its circuit throughout the body of the fœtus, till it come to the placenta, in the umbilical arteries, venefied again.

From the placenta, then, let us proceed, along the umbilical vein, which we have seen terminating in three different ways. 1st, By sending branches into the substance of the liver, the most numerous, if not the largest of which entered the left lobe. 2dly, By sending a rather larger branch to join with the vena porta, which ramifies in the left lobe as well as in the right. And, 3dly, By sending on its remain-

ing branch to the vena cava inferior. Here our attention is arrested, and questions such as the following naturally arise :—

Why is the blood of the umbilical vein, when it arrives at the liver, divided into two portions, one of which is retained in the liver, and the other goes on to the heart? Why is by far the greater part of it, more than a half, perhaps more than two-thirds, distributed to the liver? Why is that portion of it, which is thus retained for the use of the liver, distributed throughout that viscus by two sets of vessels? Why is one part of it sent throughout the liver by the branches of the vena porta, while the rest is sent, and chiefly sent, to the left lobe by branches that go direct from the umbilical vein? And, lastly, why is so small a portion of the arterialised blood of this umbilical vein, a third or a fourth, only allowed to pass on by the canalis communicans, or ductus venosus, to the fœtal heart?

In answer to the first of these questions, namely, what is the reason that so much blood is sent to the liver, it may be said, that as the liver receives, in the fœtus, as in the adult, blood in the usual way by the hepatic artery; and as it also receives all the blood which the vena porta can bring; and as it here receives the greater part of what the umbilical vein conveys, we see the reason why it grows so fast, and has acquired what may well be called an enormous size before the child is born. At the same time, one

would naturally expect that the quantity of bile which it would secrete, in the fœtus, would be proportionably great. The fact, however, is otherwise. It does secrete bile; and a considerable part of the meconium found in the intestines of the fœtus, is bile, but it is not great, and the bile found in the gall-bladder is weak in quality. But it should be remembered, that the hepatic artery, in the fœtus, is like the other branches of the aorta descendens, very small—that, of course, the branches of the vena porta abdominalis cannot be large—that venous blood seems to be necessary for the formation of bile; but that the blood brought by the umbilical vein is arterial.

When these circumstances are considered, we begin to see a reason why the bile secreted by the fœtus is neither large in quantity nor strong in quality—and the mind, ever ready to grasp at final causes, is apt to affect to see the wisdom and necessity for all this, when it reflects upon the effects of what has been called an overflow of bile in the adult; and to think what the consequences of such an increased secretion in the fœtus might be, both to mother and child.

But if the intention of sending so much arterial blood to the liver, as does, we have seen, enter it by the umbilical vein, be not for secretion, the suspicion waxes strong that it must be for nutrition; and that suspicion almost becomes conviction, when we attend to the following well-known and established facts.

The liver is a large organ, even in the adult; it fills the right hypochondrium, and stretches across to the epigastrium; but when sound, it is covered and hid by the ribs. In the fœtus, it not only fills the right hypochondrium, but occupies the greater part of the right lumbar region also; it stretches across the epigastrium into the left hypochondrium, and extending downwards, it almost touches the navel; and what must strike every attentive observer, is, even on a slight inspection apparent, the left lobe, which in the adult is small compared to the right, is, in the fœtus, so large as not only to attract attention, but to surprise us.

Now, what can be the reason of this solicitude to hasten on the growth, and to perfect the structure of the liver, when so many other organs, seemingly as important, are allowed to come on in their growth, *pari passu* with the rest; while others are apparently neglected, and their development, as it were, retarded till some after period of life? The reason that is the most obvious, and which seems to follow the most directly from the phenomena, though it may not be the only reason, is, that the liver is an organ which the infant must begin to use as soon as it is born. This conclusion, which is almost irresistible, places the liver in an eminent point of view; and I believe that if its existence as a viscus essential to life, be as great from the moment of birth, as the anxiety manifested by nature, to get it perfected and

ready for work, by the time the child is born, it is likely that the share it has, when deranged, in producing disease, is more than many pathologists are aware of.

But it may be said, how comes it that the left lobe of the fœtal liver is almost as large as the right; and what is the reason that, after birth, the right lobe grows faster than the left, so that at last they are altogether disproportioned to one another?

Before this question can be satisfactorily answered, the following circumstances should be recalled to our recollection. The liver is lodged chiefly in the right hypochondriac region; but its left lobe stretches across into the epigastrium. The stomach, on the other hand, is placed in the left hypochondrium, but its pyloric end stretches across into the epigastrium, behind the left lobe of the liver, which hangs down before it. These circumstances being considered, you will see, that if the nutrition of the left lobe had been carried on by the same means before as after birth, that lobe must have been less, than at birth it is found to be—and it is as evident, that if it had been fed as plentifully, after birth, as it seems always to be before birth, it would have gone on increasing, till it filled the left hypochondrium as completely as the other lobe does the right. In other words, it would have so pressed upon the stomach, as to have prevented it from receiving and containing the necessary quantity of food.

These circumstances being attended to, the use of and the reason for the peculiar distribution of the blood sent to the fœtal liver, comes, I think, clearly out to view, and may be placed fully before you, in the following way. In the adult, the great trunk of the hepatic artery goes to the right lobe of the liver; a branch only is sent to the left. But, in the fœtus, the left lobe receives not only its share of the blood of the umbilical vein, through the branches of the vena porta, but, as was particularly noticed, it receives several branches from the umbilical vein direct. Let it now be recollected, that in the fœtus, the whole blood in the hepatic artery and in the vena porta is venous, but the blood in the umbilical vein is arterial, and you will see that while the right lobe, in the fœtus, receives almost all its nourishment from the vena porta, the left lobe receives more than seems to be its share from the umbilical vein. No wonder, then, that, before birth, its growth is rapid. But after birth, the umbilical vein becomes impervious, and the blood in the hepatic artery is no longer venous, but arterial. And now we also see, that effects being proportionate to their causes, the right lobe receiving by far the greater proportion of the blood which the hepatic artery conveys, the growth of the left lobe must now receive a check, while that of the right must rapidly increase. So that, by this varied and altered distribution of the arterial blood, the left lobe is made to grow fast before birth, that

it may be ready to perform its functions, as soon as the child is born; but it is made to grow slowly after birth, lest it occupy that room which the stomach should fill.

It is perhaps more difficult to explain, why a portion of the blood of the umbilical vein is sent into the system of the vena porta. The vena portarum conveys into the liver the blood of the chylopoietic viscera, both in the fœtus and in the adult; and from this venous blood, there is reason to believe, the bile is chiefly secreted; but, in the fœtus, this vein not only receives all the venous blood from these viscera, as in the adult, but a large proportion of the blood that is arterial from the umbilical vein. Is it not probable that dilatation and extension, as well as nutrition, is here kept in view? that the sescerning part of the viscus may be ready and fully able to receive the increased quantity of blood, which is to be poured into it very soon after birth, from the dilated veins of the abdominal viscera? Here then, again, we see an anxiety to get the liver evolved, and prepared for use. The vessels of the vena porta are dilated and perfected by the umbilical blood, sent before birth for nutrition, that they may be ready after birth for secretion. All these circumstances are hints, shewing that the secretion of the bile is a great and important work, and that the liver is one of the principal organs in the animal economy. There are three organs particularly eminent as purifiers of

the blood. They may be said to be drains to carry off impurities.

The first of these, in importance, certainly is the lungs; the second the kidnies; the third the liver. As for the kidnies, they obviously separate from the blood much of the superabundant watery part, together with saline matter. The lungs give vent to its superabundant gases, especially its hydrogen and carbon. But what is secreted by the liver? To say that it is the bile, is not altogether satisfactory. But when it is recollected, that the bile contains a great proportion of oil, and that the principal constituent principles of bile are carbon and hydrogen, the chief ingredients in venous blood, the liver then comes forward to our view, as an auxiliary to the great function of respiration; and it would seem, that as all the blood, that arrives at the right side of the heart, must pass through the lungs, to be purified, so must all the blood from the chylopoietic viscera pass through the liver, and receive a preparatory purification there, before it can be permitted even to enter the heart.

As a corollary from this, it should follow, that those animals which enjoy the benefits of respiration in an inferior degree, should have that made up to them by the extent and perfection of their biliary system; and this, on examination, is found to be the case. Fishes and all cold-blooded animals require less air for the purification of their blood, than is

required by hot-blooded animals; and the whole of the blood of many of them is not even sent to their gills; but their liver is very large. The whale tribe, however, have lungs. But as their supply of air is precarious; as they are sometimes, while in pursuit of their prey, obliged to be long under water, and cannot so regularly and at all times get a fresh supply; they are provided with a liver of enormous size, which, by separating the hydrogen and carbon, the chief venefying principles in blood, and combining them in the form of oil, in the bile, leaves less of these venefying principles to be separated and cleared away by the lungs. And when it is considered that the bile is poured into the intestinal tube, not near its inferior end, from whence it might have been easily expelled, but into it, at its upper end, near to its beginning from the stomach; that it is mixed and intimately blended with the food, in its passage from the pylorus to the anus; that it assists in the formation and separation of the chyle; that it lubricates the internal surface of the intestines, and stimulates and promotes their peristaltic action; we see that the liver is an organ that plays a most important part in the animal economy; and, in particular, that while it is an emunctuary, which clears away principles, which, if retained, would be injurious, it is an organ that can combine these very principles anew, and form of them a most useful secretion.

Having thus seen what are the uses of those

branches of the umbilical vein that ramify in the liver, and of those that join the system of the vena portarum, we may follow the continuation of the umbilical vein, the ductus venosus. It joins, we have seen, one of the hepatic veins, as these are about to enter the inferior cava, which ascending up through the diaphragm terminates immediately in the right auricle of the heart. And here it should be remembered, that the blood which this ductus venosus brings, is arterial blood, while all the rest of the blood that is poured into the right side of the fœtal heart is venous: for the blood of the coronary vein has circulated through the substance of the heart, and has been venefied there; and all the blood which is poured into the heart, by the vena cava superior, has circulated through the head and upper extremities, and been venefied also. But the blood in the canalis communicans, the ductus venosus, comes directly from the placenta, and has been found by actual observation to be arterial; and, in its course to the fœtal heart, it has neither suffered change by muscular action, nor by glandular secretion.

At the same time, it should be considered, that perfectly arterial it cannot be; for, granting that it had come directly from the left side of the mother's heart, still it must have become venefied in some degree, by coursing along her aorta, her hypogastric, and her uterine arteries; it must have been still more venefied by having come into contact with the venous

blood of the fœtus in passing through the placenta; and, lastly, it must have become still more venefied before it can be brought from the placenta to the vena cava by the umbilical vein.

Or, if we adopt the opinion which supposes that the fœtal blood does not pass through the placenta to the mother, but is purified in the placenta, and that it returns back immediately to the fœtus; still it must be recollected, that the arterial blood of the mother, in the placenta, cannot have a stronger attraction for the venefying principle, than is possessed by the fœtal blood itself. Therefore, supposing the one to be venefied plus, and the other minus, the venosation of the one cannot be diminished below, nor the arterialization of the other raised above the mean; while, on the other hand, the arterialization of the blood, in the umbilical vein, must, after it leaves the placenta, suffer diminution, before it can arrive at the fœtal heart. It cannot be more, but it may be less, considerably, than half so much arterialized, as is the blood of the adult, when it leaves the lungs.

Our ideas respecting the purity of the umbilical blood being thus chastened, we may turn our attention to its quantity. Authors differ very much on this point. But if, after comparing the umbilical arteries with the aorta descendens, we suppose with some physiologists that nearly one-third part of the whole blood that passes through the fœtal heart, at

every systole, is conveyed to the placenta, by the umbilical arteries; and, in the next place, take it for granted, that the blood, which is returned to the right side of the fœtal heart, is but half arterialised; we shall, perhaps, be not far from the truth, if we suppose, that the sum total of arterialising effect which this blood of the umbilical vein can produce, on the whole blood in the body of the fœtus, cannot be more, though it may be less, than one-sixth of that which is produced on the blood of the adult, by the air in the lungs, during respiration. Nay, as more than two-thirds of the blood in the umbilical vein is expended on the liver, there would be reason to believe, that if, as is generally supposed, all the blood, which enters the right auricle of the fœtus, be mingled together, the degree of its arterialization could not be more, though probably it would be less, than one-twentieth that of the arterial blood of the adult; which excites a suspicion, that this arterialised blood, of the ductus venosus, is not permitted to mingle with the venefied blood of the upper cava and coronary vein; and when the effects of arterialization are considered, and when we reflect on the situation in which the fœtus is placed, and the source from whence its nourishment is derived, a low degree of arterialization seems to be as much as it can need, and that more would have done it harm; for it should be remembered, that as the fœtus is nourished either by a secretion from the arterial blood of the mother,

or by arterial blood alone, the venefying principle in its blood can neither be large in quantity, nor strong in quality. Therefore, the fœtal blood requiring less purification than that of the adult, stands less in need of an excess of the purifying cause. It should also be considered, that the generation of heat, in the animated machine, seems to keep pace with the degree of arterialization, and that irritability and the rapidity of circulation are intimately connected with one another. But arterial blood is a stronger stimulus to the heart and arteries, and to the whole system indeed, than venous blood; therefore if the blood of the fœtus were to be as highly arterialised as the blood of the adult, the sensibility of the young animal would be rendered too acute for its situation, and the degree of heat which it would generate would, when added to that of the uterus, accumulating around it, be more than its delicate frame could endure.

There are, perhaps, other reasons why the fœtus in utero needs less of the arterialising principle than the respiring animal requires. Cold-blooded animals have few red muscles, and there is in their composition a great proportion of albumen and gelatine. The fœtus, in the early months of pregnancy, is almost a jelly. High arterialization seems incompatible with that condition. But that condition seems to be the most favourable for evolution and growth. To effect, therefore, the formation of that nidus, in which, afterwards, when the arterialization becomes

more perfect, the more completely organised parts are to be laid, the arterialization must be kept low.

Having seen the last branch of the umbilical vein, the ductus venosus, pour its contents into one of the short hepatic veins—and observed that this hepatic vein enters the vena cava near to its posterior side, we see that the blood of the ductus venosus, when it enters the auricle, must be at the posterior side of the stream of the inferior cava, and, of course, in contact with the front of the posterior wall of the auricle, which is, you know, in and formed by the septum. Following the vena cava, then, we may enter the fœtal heart; and here three peculiarities, namely, the foramen ovale, on the one hand; the ductus arteriosus, on the other; and the collapsed or unexpanded state of the lungs, present themselves, all at once, to our view.

This crowd of peculiarities renders the subject apparently confused and obscure. But if we separate them from one another, and endeavour to ascertain the situation, the structure, and the particular function of the organs concerned in each, the use and the necessity for each and all of them comes successively into view, and the whole is seen to be beautifully simple and complete.

In attempting to explain all this, I have sometimes begun with one of these peculiarities, and sometimes with another. But from experience, I have found, that if I began either with the foramen

ovale, or with the ductus arteriosus, I never failed to get, by the anticipations which I found to be necessary, engaged with all the three; till, at last, the whole explanation became perplexed and confused. Of late, I have found it most convenient to begin with the unexpanded state of the lungs; which, though a peculiarity not so apparent as some of the rest, gives occasion for the other too. Let us begin, then, with the fœtal lungs.

In the adult the lungs are so capacious, and the branches of the pulmonary arteries are so pervious, that they permit all the blood that is sent from the right side of the heart to get through them to the left. But in the fœtus they are in a very different condition. The child in the womb is bundled up, as it were, in a confined situation. The head is bent forward, so that the chin rests on the breast; the thighs are squeezed up, so as to touch the belly; the legs cross one another, and are folded so as to touch the hips; while the arms lie bent between the knees and the chin. The different parts seem, indeed, to be so folded together, and to be so compressed, as if some external force had been applied, all around, constraining them to adjust themselves, so that the whole shall assume that figure which occupies the least room. In this situation the sternum and the ribs are pressed inward, while the abdominal viscera are squeezed upward, forcing the diaphragm to ascend; by which means the capacity of the thorax is

diminished to the uttermost, in all its dimensions. And when we consider, that in this state, the vessels of the lungs must not only be squeezed against one another, and their capacity be lessened by compression, but that they are shortened by their own natural elasticity, nay that many of them are crumpled up and made to lie in gathers, by which means the impediments to the free circulation of the blood through their flattened, shortened, and tortuous tubes, must be greatly augmented; we become satisfied that till the sternum and ribs rise, and the diaphragm descend, and till the vessels of the lungs be unfolded and stretched out, the whole of the blood of the right side of the heart can neither be received nor transmitted by the lungs. And when we reflect on the matter, we see that if the sternum and ribs were to rise, and the diaphragm to descend, while the child was in the womb, the lungs behoved to expand also, else between the surface of the unexpanded lungs and the receding parietes of the thorax a vacuum would be formed. But the parietes of the thorax cannot expand in utero; else the liquor amnii would enter, and fill the lungs, and the lungs, we know, cannot, and do not expand of themselves. On the contrary, they are endued, through life, with a native inherent elasticity, the constant tendency of which is to resist dilatation, and to bring them back to their original unexpanded state. Besides, the child is surrounded not by one membrane, but by

two, which are continuous cists that envelope it all around; and, as if all these were not sufficient to prevent the external air from getting access to its lungs, the fœtus is surrounded by and swims in the liquor amnii. It may be said that, in all probability, this liquor amnii does enter. But if it did, then, in the lungs of the healthy new-born child it should be found—and if the lungs were filled with this water, what room could there be for air, after the child was born? Till it was discharged the child could not respire; and if the discharge of such a quantity of fluid as could fill, or even partially fill, the lungs, were to be the first act of the new-born living child, which to permit of respiration it behoved to be, it should, long ago, have attracted notice, but by no one, so far as I know, has it ever been seen.

What, after all, it may be said, can prevent the liquor amnii from getting down into the fœtal lungs? It swims in this water, and its mouth is open; what can hinder the water from getting down? If there be but a nisus to raise the ribs, or make the diaphragm descend, the liquor amnii should be solicited to enter. This leads us to another, and a beautiful instance of the great truth, that we are fearfully and wonderfully made!

The larynx bears the stimulus, and seems to be gratified by the touch of pure atmospheric air. But the whole of its muscles are thrown into instantaneous and convulsed action, by the touch of any other thing.

Liquids are instantaneously rejected; and solids are as immediately thrown out by involuntary and unrestrainable coughing. This peculiar irritability inherent in the parts about the glottis, is the guard, the watch, set at the very door of life, even before we are born—so that a particle of the liquor amnii could no more be permitted to enter the wind-pipe of the living fœtus in utero, than a mouthful of ardent spirit could be permitted to pass the rina glottidis of the adult. The glottis, therefore, is completely shut—so that till the epiglottis rise and the rina open, nothing can get into the lungs, neither can the sternum or ribs rise. Therefore, so long as the fœtus is in the shut uterus, its lungs are and must be in a state of collapse, if such a word can be applied to a part that never was expanded before; and so long as the lungs remain in this their primitive unexpanded state, the compressed and crumpled up branches of the pulmonary arteries and pulmonary veins neither can receive, nor transmit all the blood, which the right ventricle sends out from the heart. Here, then, we see an absolute necessity for some side opening, some passage, some collateral tube, to convey past the lungs, to the left side of the circulatory system, all that quantity of blood, and it is not small, that is sent out from the right side of the heart, but which the fœtal lungs cannot receive.

This passage, in all the animals with which we are best acquainted, is the ductus arteriosus, the third,

and by far the largest of the three branches, into which the pulmonary artery of the fœtus divides. It terminates, we have seen, in the aorta, immediately after that artery has sent upward from its arch the vessels that go to the head; and, of course, just after it has begun to assume the name of aorta descendens.

And now, having followed, from the right side of the heart, that quantity of blood which the lungs could not receive, and seen it fairly conveyed, not into, but past the left side of the heart, and not even into the aorta ascendens, but into the aorta descendens, by the ductus arteriosus, we may return, and go along with that portion of the blood of the right ventricle, which the lungs do receive, by the two ordinary branches of the pulmonary artery.

The quantity of this blood, conveyed to the lungs, by these two branches, has been variously estimated by different authors. But, for the sake of illustration, let us take it at the half of that which the right ventricle throws out, into the trunk of the pulmonary artery itself; then, it is to be recollected, that all the blood which the pulmonary artery receives from the right ventricle, passes through the lungs of the adult: and, as that quantity was the whole that the right auricle gave, it is evident that, in the adult, the capacity of both auricles must be nearly the same. But, in the fœtus, how is the left auricle to be filled? since more than a third, nay a half of the blood which

the right auricle gives, is sent away by the ductus arteriosus, to the aorta descendens, and cannot get to the left auricle at all. But if that auricle be not filled, in time, to contract with the right, how is the left ventricle to be filled? and if the left ventricle be not filled, in time, to contract along with the right, how is the circulation to be carried on?

These questions lead us to look about, most anxiously, for some opening, some hole of communication, between the right auricle and the left, through which as much blood may be sent, as will make up the deficiency of that returned from the lungs; and which shall, by filling the left auricle as fast as the right fills, ensure the synchronous contraction of both. This brings us, you see, to the foramen ovale, which, with its valve, was pointed out to you, as one of the most obvious and best known peculiarities of the fœtus. Through this opening the blood of the right auricle may easily pass; and through it, as much does pass, from the right into the left auricle, as compensates for what the left does not receive from the lungs.

There is no opinion, however just, and no fact, however obvious, that may not be contraverted, and that plausibly, too. Mery, a French Anatomist of considerable note, was at great pains to prove that, in the fœtus, no blood passed from the right auricle into the left, through the foramen ovale; but that, on the contrary, a quantity of blood came, through that hole,

from the left auricle to the right. I will not take up your time in examining this very strange opinion, which is now, I believe, generally abandoned.

But though it has been generally agreed on that Mery's opinion was wrong, another question came to be agitated, and is agitated still, which at first sight seems to be more of a curious than useful nature. It may be stated thus, " Is it the blood of the upper or that of the under cava that passes through the foramen ovale, from the right into the left auricle? or are they both mingled together, in the right auricle, and does a portion of both go through conjoined ?"

I shall not trouble you with a history of the controversy, to which this question, in former times, led; but state shortly, that while many held, and do hold, to the more obvious opinion, namely, that the blood of the two cavæ and that of the coronary vein came all into the auricle, at one and the same time, and from three different points, and tended all toward the centre of the cavity, and there met, and were mingled together, and that then what of this mixed mass the right auricle could spare, passed through the foramen ovale, into the left auricle, till both auricles were equally filled; others, and among the rest Haller and Winslow, were of opinion, that the blood of the cava inferior alone passed through the foramen ovale, into the left auricle, while the whole blood of the upper cava and coronary vein was retained in the right.

"This last opinion," says Mr. John Bell, who, in modern times, has entered keenly into this controversy, "is the puerile theory which, modified in various ways, amused the French Academy, or rather was the source of a perpetual civil war in it for more than a hundred years; and that there might be no ambiguity," he adds, "in what they said or meant, Sabatier pronounces plainly that the Eustachian valve is of use only to the fœtus, and that there are two opposite currents in the right auricle of the heart; that the one goes from the lower cava upwards to the foramen ovale, while the other from the upper cava descends right into the opening of the ventricle. What," says Mr. Bell, "shall we say of anatomists who, in the narrow circle of the auricle, conceive two currents to cross one another, as the arrows by which such currents are usually represented in a map? This is, in reasoning," he adds, "below all criticism. It carries us backward 100 years in anatomy and physiology; and yet this is all that Haller and Winslow and Sabatier, and a mob of others, have been able to say, in proof of the connection of the Eustachian valve with the circulation of the fœtus."—Having thus given his decided opinion, that no part of the blood of the cava is directed, unmingled, into the left auricle, through the foramen ovale, he has judged it right to settle the use of the Eustachian valve, which Sabatier has said is useful to the fœtus, and this he has done shortly, by saying, "that the Eustachian valve has

no connection with the fœtal circulation whatever. Its use," he says, "is to the adult; and that use," he asserts, "is to eke out the imperfect wall of the auricle, and to gather the blood of the auricle through the ventricular hole."

On the last part of this statement, we now surely need not dwell, for the use assigned in it, to the Eustachian valve in the adult, has been but lately before us; and we have seen, that the wall of the auricle is not imperfect; that were it imperfect, the Eustachian valve could not assist it, in gathering the blood of the auricle in through the ventricular hole; and, lastly, that it is of so little use to the adult, that it is, in general, more or less broken down, and, in old people, it is very frequently altogether wanting: and if, as Mr. Bell says, it be of no use to the fœtus, why, what between the one set of anatomists and the other, this valve, the Eustachian valve, the valvula nobilis seems to be discarded altogether. There must be some mistake in all this, for the valve, though broken at times, and often wanting, in the adult, is always present, and in general is entire, in the fœtus; though in the very young fœtus it is small, and nature does nothing in vain.

Leaving, however, this hesitation, for the present, we may proceed to see what are the proofs that the blood of the cava inferior is not permitted to go through the foramen ovale, by itself; but is mingled with the blood of the cava superior and coronary

vein ; and that the left auricle gets from the right, through the foramen ovale, what it needs from the mixed mass.

" Every drop of blood," Mr. Bell says, " that comes into the fœtal system, is, either by the powers of the placenta, or by communion with the mother's system, oxidated blood. One part of this blood passes through the circulation of the liver, before it reaches the heart ; while another passes directly through the ductus venosus, or canalis communicans, to the heart. But both are mixed, and the blood is all of one quality when it arrives at the auricle, in order to fill the heart, and to begin its course round the body. Now," he adds, " since the blood is all of one quality, nature can have no cause for dividing such blood into two portions ; one to pass through the lungs, and the other to pass over the body ; she can have no motive for employing, as in the adult, two hearts. The design, therefore, of nature," he concludes, " plainly is to prepare a double heart, and keep it in reserve for the circulation of the adult, but to use it as a single heart in the fœtus : and simply," he continues, " is all this accomplished. For the two auricles communicate so freely by the foramen ovale that they are as one. The two ventricles deliver their blood into one vessel, the aorta ; therefore the two ventricles are as one. The blood arrives by the cavas, fills the right auricle, and at the same moment flows, through the foramen ovale, into the left auricle, so

that the auricles are as one, and filled by one stroke. The two auricles act at once, and so the ventricles are filled at one stroke. The aorta receives the blood of both ventricles, at one stroke; so that, in the strictest sense of the word, the fœtus has but one single heart, the heart of the body, the function of the lungs being performed by the placenta, far from its proper system; and when the functions of its own lungs begin, then nature, by the simplest of all mechanisms, divides the two hearts, that they may perform each its proper function.

"First, the flow of blood, into the lungs, deprives the ductus arteriosus of blood; and, secondly, this flow of blood coming round to the left auricle of the heart, restores the balance, presses down the valve of the foramen, and makes the partition perfect. In short, while the oval-hole and the ductus arteriosus are open, it is a single heart; and when they close, as they do, the moment the child is born, it is the double or perfect heart."

Now, nothing can be more luminous, or more distinctly and forcibly expressed, than all this; and if all the premises, upon which the reasoning rests, be taken for granted, the conclusion, without doubt, cannot be resisted. At the same time, every one must be pleased with the beautiful and clear view, given of the single heart of the fœtus, and of the double heart of the adult; nevertheless, as I am satisfied that some of the facts stated have never been

proven, and that others of them never will be proven, a doubt and a suspicion remains, which calls for farther inquiry.

The first circumstance which attracts notice, in the statement that has been given, is, that "every drop of blood that comes into the system of the fœtus, is, either by the powers of the placenta, or by communion with the mother's system, oxidated blood." But though all this may be very true, it should be remembered, that it is not respecting the blood that comes into the system of the fœtus, that we are in any doubt; it is with regard to the blood that comes into the right side of the fœtal heart, that there can be, *in limine*, any hesitation or doubt. And here it is needless to observe, that the manner in which the statement is put, is misleading—for the blood that enters the right auricle is not all of one kind. That of the upper cava and coronary vein is altogether venous; that of the cava inferior is partly arterial; and the question ought not to be, whether the blood that enters the system of the fœtus be all of one kind; for, with regard to that, there can be but one opinion: but as the blood, in the right auricle of the fœtal heart, is of two different kinds, the question is, and ought to be—Does nature, or does she not, keep these two kinds of blood separate, in the right auricle; and, if she does, is one of these kinds, thus kept separate, sent to circulate through the lungs, and is the other sent to circulate throughout the body? or,

does she allow them both to be mingled together in the right auricle, and sent indiscriminately over the whole system? Mr. Bell has not thought it necessary to look for proofs, in this matter, drawn either from anatomy or experiment; but, apparently satisfied with the beauty of the theory he had formed, and pleased with the facility with which it explained many of the phenomena, has concluded rather hastily that nature could have no motive for dividing this blood, that came into the fœtal system, into two portions; one to pass through the lungs, and the other to circulate over the body. Here, however, it may be said, and without presumption, that if we see nature dividing the blood that comes into the system of the fœtus, in one instance, we need not be surprised if we find her doing it in another. Now, it has been already shewn, that she divides the umbilical blood into two portions, before it gets to the auricle; and sends one portion of it, so divided, to circulate through the liver of the fœtus, while she carries on the remaining part of it to the fœtal heart. And having seen and marked this, we need not be very much surprised, if, on continuing our observation, we find her using means, equally simple as efficient, to prevent that which she had thus separated, from being mingled with the blood of the cava superior, or even with that of the coronary vein.

But waving, for the present; these considerations, and taking it as granted, as the theory does, that the

blood of the cava superior meets with and is completely mingled, in the right auricle, with the more arterial blood of the cava inferior; and that they pass through the foramen ovale indiscriminately together; and that the great aim of nature is to prepare a double heart for the adult, but to use it, by means of the foramen ovale and ductus arteriosus, as a single heart for the fœtus, that the whole force of the two ventricles, as Mr. Bell has said, may be thereby obtained, to propel the blood along the aorta, to circulate in a distant organ, the placenta; supposing all this to be duly considered, we may next inquire how this very ingenious theory—and ingenious and beautiful it must be allowed to be, will agree with the anatomy of the parts, and account for some of the most remarkable of the phenomena.

It is taken for granted by the theory—it is, indeed, the principal point on which it rests, that a greater force is required to urge the blood of the adult through the minute branches of the aorta; yet with respect to this supposition, there is reason to doubt. With regard to the circulation of the blood through the head of the fœtus, there is no apparent peculiarity; it seems to be the same after birth as before it: the blood circulates in the same vessels, and is urged on by the same power, viz. that of the left ventricle of the heart, which sends it up both before and after birth, through the aorta ascendens to the head and upper extremities. But the case is

far otherwise with the other parts of the body. The arteries of the thorax, of the abdomen, of the pelvis, and of the lower extremities, are, in the fœtus, we have seen, very small; and they do not seem to be so pervious as the vessels of the placenta, for the blood, instead of entering them freely, passes on to the placenta by the large and capacious umbilical arteries, leaving the rest of the system of the aorta descendens, comparatively speaking, dry.

Now, what can be the meaning of this? Why is not the combined force of the two hearts of the fœtus united into one, and acting on the blood of the aorta descendens, able to force the blood as copiously into the diminutive and unexpanded branches of that vessel, and make them dilate, as the force of the single heart, the force of the left ventricle alone, is able to force the blood of the aorta ascendens up through the vessels of the fœtal head, or as that single ventricle is able to force the whole system of the aorta descendens to dilate, immediately after birth? If in the one case, we see a rapid growth and a speedy development, the effect of the force of a single ventricle, why should we not see a greater increase and a more perfect and speedy development in the parts to which the blood is sent by the combined energy of two? The cœliac, the mesenterics, the hypogastrics, and all the branches of the iliacs, should yield to the impetuous tide, and become dilated and capacious, and the parts to which they are sent should,

before birth, be very much grown. But the reverse of all this is the case. A suspicion, therefore, arises, that instead of a greater force being necessary to throw the blood of the aorta descendens through the placenta, less is required, and less is actually given.

This will appear, when it is considered, that the powers of the two ventricles are by no means equal. Of this you must already be satisfied, from what you know of the parts. But you will be convinced of it the more, when you reflect, that the wall of the left ventricle is more than double the thickness of that of the right; and that the force of each is in proportion to its muscular mass. You will be assured of this when you consider that the one, the right ventricle, has to send the blood through the lungs, or to effect the lesser circulation only, while the left has to perform the greater circulation, or to send the blood all over the body.

What, then, will be the effect of both the right and left ventricle on a column of blood that is to be sent through the placenta? At first sight, and without giving the matter much consideration, we would be apt to say, with the theory, that the blood would go on with a double momentum; but, when we reflect that this column of blood, if it had been sent by the force of the left or strongest ventricle alone, would have proceeded with a greater velocity than if it had been sent by the right, we begin to see, that if part of it be sent, as in the pulmonary artery and ductus

arteriosus, with the force of the right ventricle, while that in the aorta ascendens is sent with the force of the left, the whole mingling in the aorta descendens must move on with a less impetuous stream.

This might be illustrated by many examples drawn from the laws of matter and motion: I shall take a familiar case, and suppose that two grey-hounds start in a chase, and that the one is much fleeter than the other. The result, you all know, would be, that, barring accidents, the one would very soon outstrip his less nimble neighbour. But suppose them to be coupled together; then it will be seen, that the speed of the one must very soon be checked by the slow pace of the other: the one that is fleet, may increase, and indeed will increase that of the other, by dragging him on; but by so much as the speed of the slow one is less than his own, must his speed be retarded, for being coupled, they must go on together.

Apply this to the present case. Let it be supposed that the force of the left side of the heart is as 100, and that the velocity of the blood which it throws out along the aorta ascendens, is as 100 also; and let it be supposed that the force of the right ventricle is equal only to 50, and that, of course, the velocity of the blood which it sends along the ductus arteriosus, is no more than 50; then, you will see that, by the time the blood sent by the left ventricle, along the aorta ascendens, moving with a momentum

of 100, comes to be mingled with the blood sent by the right, along the ductus arteriosus, and moving with a momentum as 50, the whole, thus mingled, instead of moving on with a momentum as 150, which the theory seems to take for granted it must do, as two ventricles are concerned instead of one, will proceed with a momentum that can be no more than 75, which is the mean of their respective propelling powers.

It is obvious, therefore, that though nature does prepare a double heart, but uses it as a single heart in the fœtus, that is not to give strength, but to impair it; not to accelerate the motion of the blood, but to retard it; and when the placenta is examined, the reason becomes plain. The vessels of the placenta are so capacious, and have such a free intercourse with one another, that if an injection be thrown in by the arteries, it returns by the veins, or if by the veins, it returns by the arteries; so that the course of the blood is patent and free.

Still, however, it may be said that, though the ingenious author seems to have failed here, in making out the use he has assigned for these peculiarities of the fœtus,—though he be not borne out by facts, in maintaining that, in every case, two must be better than one; he may have reason on his side, in asserting that the blood of the inferior cava is not kept separate from that of the upper cava, in the right auricle of the fœtus; he may be right in asserting

that both must be mingled together, before any part of them goes through the foramen ovale; and he may be correct in supposing that the Eustachian valve has nothing to do with the circulation of the fœtus. The question then, now, is simply this: Does the blood of the cava inferior, in whole or in part, pass through the foramen unmingled with that of the cava superior, or coronary vein? And here we shall find the discarded Eustachian valve coming prominently forward, and playing a most conspicuous and important part.

This valve, you have seen, is interposed between the foramen ovale, and the mouth of the coronary vein. It is shaped, you saw, like a crescent. Its posterior cornu begins on the front of the septum that separates the two auricles from one another, as high up sometimes as the transversalis muscle, or isthmus of Vieusenius. It descends along the left edge of the left columna of the foramen ovale, increasing in breadth, and its free border projecting farther from the wall, as it descends, till it reaches the bottom of the auricle, at which point it is, in the full-grown subject, more, at times, than half an inch in breadth (*figs.* 8, 9, 10, 13). Here it is, opposite to the mouth of the coronary vein. It then turns upwards, and gently to the left, along the posterior or inner surface of the anterior wall of the auricle, and ends by turning narrower and narrower as it ascends, till its evanescent cornu, now more than an

inch from the bottom, can be no longer seen. That border of it that is rooted in the auricle, takes a longer sweep than the other, which floats free. So that, as its cornua both bend to the left, it has, when raised, the appearance of a sail, the back of which, you saw, looked towards the foramen ovale, and mouth of the inferior cava; while its bosom looked towards the lower half of the foramen ventriculare; and its deepest and most capacious part was opposite to, and may be said to conceal the mouth of the coronary vein. Formerly, when speaking of this valve in the adult, it was said, that during the diastole of the auricle, it directs the current of the blood entering by the coronary vein, upward along a gutter or groove, that lies immediately between it and the foramen ventriculare; so that the stream winding gently upwards, and to the left, is made to set in against the back of the raised up and insensible tricuspidal valve. Now, it may be said, that were it not for this Eustachian valve, in the fœtus, the blood of the coronary vein would, from the direction of its current, take across the cavity of the auricle, and holding on upwards and to the right, in an oblique direction, would endeavour to pass through the foramen ovale, from the right auricle into the left, were it not that this valve, the Eustachian valve, is raised by the very first gush of blood from the coronary vein itself; whereby the whole blood that issues from that vein, is turned away from the foramen

ovale, and is directed upwards and to the left, towards the foramen ventriculare, which is quite the other way.

Now, the question that naturally arises here, is this: If nature can have no design in keeping the blood of the under cava separate from the rest, what can be the reason of all this seeming anxiety and care, to prevent the blood of the coronary vein from getting across the cavity of the auricle, and mingling with the blood of the under cava? It does not seem to be intended that these two kinds of blood should never meet; for, after birth, the Eustachian valve begins to decay; and then the blood of the coronary vein gets freely across the auricle, and mingles thoroughly with all the blood that is there. It is, therefore, only during the fœtal state, it would seem, that nature is anxious that they should not meet, and be mingled together; and if she does shew so much solicitude to prevent their meeting, before birth, as to have thought it necessary to create a temporary organ, to prevent their getting into contact with one another then, which organ she removes, after birth, by allowing it to be broken down, to be absorbed, or to go entirely into decay, is there not reason, and strong reason, too, to suspect, that in all this, there must be some ulterior and important design?

It was mentioned formerly, when speaking of the Eustachian valve in the adult, that, as the current of the blood enters the auricle from the cava superior

obliquely, from above downwards, and from behind forwards, it seems as if intended that it should strike against the raised valve of the foramen ventriculare, about or a little below its middle. But as the isthmus of Vieusenius projects a little from the wall of the auricle, and throws the current of the upper cava forward, and a little upward, as a little bump or gentle rising on the inner side of the muzzle of a gun gives a new direction to the bullet, just as it is about to start away, so this swell of the constrictor magnus, the isthmus of Vieusenius, the tubercle of Lower, the transversalis auriculæ, raises the current of the upper cava a little, and directs it so, that it must strike against the back of the raised tricuspidal valve, a little farther up than it otherwise would do; but still the tendency of the current being downward, it must impinge obliquely, and be directed downwards, and to the left, till reverberated to the right, and brushing along the bottom of the auricle, it would arrive at the very mouth of the cava inferior, and, attempting to penetrate into its current, would materially interrupt the free entry of its stream, were it not that the Eustachian valve, the despised Eustachian valve, raised by the current of the coronary vein, stands in the way. By this valve it is not only opposed, and brought to stagnation, so that the blood of the coronary vein may be allowed freely and quietly to enter; but the blood of the upper cava itself is not allowed to pass across the lower part of

the auricle, with its impulse unabated; or to strike against the current of the inferior cava, with undiminished momentum; therefore the blood of the inferior cava also is allowed to enter freely and undisturbed.

But it may be said, that, allowing all this to be true,—granting that the Eustachian valve is of little or of no use to the adult,—and supposing that, in the fœtus, it not only opposes and prevents the current of the coronary vein, but of the upper cava, from whirling along the bottom of the auricle, and mingling with the blood of the under cava directly, and with all the force of unimpaired momentum; yet, the Eustachian valve can do no more than lessen their impetus, and bring them to stagnation. They must, as soon as the bosom of the valve is filled, overflow its brim, and get, not only to the blood of the cava inferior, but with it go through the oval hole.

Why, it certainly is true, that the space between the valve and the ventricular foramen, is not large enough to contain all the blood which the cava superior and coronary vein bring. Some of it must overflow; but it is not so clear that what thus overflows, either does or can get through the foramen ovale; for, it should be recollected, that the blood which has thus risen over the valve, has been checked in its career, and brought almost to rest by the valve; whereas the blood of the under cava has met with no obstruction to impede its course: it is pouring into

the auricle like a strong and rapid stream ; and every one may form some conjecture with regard to what is likely to happen, when the eddying current of the upper cava approaches, and comes into contact with this impetuous tide ; by reflecting on what he must have often seen, when standing, after a summer shower, by the side of some rapid but transparent stream, and marking the approach of the muddy water of a sluggish upland meandering rill. It attempts to mingle with the limpid water of the more rapid current ; but it is not permitted to enter : it is elbowed off, as it were, and thrown aside, as if the more pure and powerful tide disdained its contamination : so it must happen to the blood of the coronary vein and upper cava. The blood of both, according to the laws that regulate the force of bodies in motion, is and must be dashed aside, by the blood of the under cava ; and so far from being allowed to pass through the foramen ovale, along with it, they will not even be permitted to mingle with its more pure and more impetuous tide. And here it may be observed, that as no more blood is needed in the left auricle, than will make up for that quantity which is sent past the lungs by the ductus arteriosus, and no more can be received, the ductus arteriosus becomes the measure of the quantity of blood which actually does pass through the foramen ovale. But the ductus arteriosus is less than the inferior cava : therefore the whole quantity of blood, in the inferior cava,

cannot be allowed, and is not allowed to pass through the oval hole.

The blood, therefore, of the cava inferior, must be divided into two portions,—and while one part of it is sent through the foramen ovale, the other must be turned aside into the cavity of the right auricle. Now, that this is actually done, is distinctly seen in the heart of the ox, and other quadrupeds; and the manner in which it is done there, being somewhat more simple than in the heart of the human fœtus, it illustrates the process in both. The isthmus of Vieusenius, or tubercle of Lower, in that animal, is so large, and projects so far into the cavity of the auricle, and is situated so low down in it, and lies so directly over the mouth of the inferior cava, that the blood of that vein coming up in a full stream, strikes directly against the under side of the tubercle, and is split by it into two portions; one part of it going through the foramen ovale, into the left auricle, while the other is forced aside into the right. Here there is no crossing; for the tubercle is placed so low down in the auricle, that what of the blood of the inferior cava is split off by it, and directed through the foramen ovale, can scarcely be said to have entered the auricle at all.

There is another circumstance, with regard to the heart of this animal, which merits notice. The tubercle of Lower, which, in this animal, is no mere imagination, being situated so low down in the auri-

cle, the current of the upper cava whirling along the bottom of the cavity of the auricle, cannot get through beneath the tubercle to get at the foramen ovale; on the contrary, it is reverberated upwards and to the right, by the bottom of the auricle, and impinging against the side of the tubercle, is directed upwards and in behind the current of the upper cava that is coming down, while the blood of the under cava struck off by the isthmus, and entering the auricle quietly, is caught by the tide, and both holding on together, strive to pass up behind the current of the upper cava, like a ground tide, and to escape up into the upper region of the auricle, where, when the two united do arrive, they enter the mouth of the creek or bay of the auricula, or lappet, almost in a direct line; where their force is soon spent, and they are brought, comparatively speaking, to a state of stagnation and rest. This is, perhaps, a new view of the use of the auricula, or lappet, a part that hitherto has attracted but little notice, and by some has been said to be of no use. But the use here assigned to it, is an use that seems to be countenanced not only by its figure, and place, and structure, but by the direction which the currents must get, from the shape and place of the parts by which they are bounded.

Another corollary, relating to these parts, in the fœtal heart of the calf, solicits our attention, viz. that if the blood which the left auricle needs, be sent to it from the cava inferior, without ever being

allowed to enter the general cavity of the right auricle, and if part of the blood of the inferior cava that is not needed in the left auricle, be turned aside into the right, where it mingles with the blood already there; and if it pass up behind the blood of the upper cava, that is coming in, then here, there is crossing of currents, and crossing in a way that few of us thought of before; at the same time, it is evident that, as in this kind of heart, the blood of the upper cava is thus reverberated upwards within the right auricle, and from the direction of its current, is prevented from getting at the oval foramen, there is no need for any Eustachian valve. Accordingly, the fact is, that in this animal, there is none. So that the very want of this valve, in the calf, the sheep, &c., which formerly used to be urged against the use of an Eustachian valve at all, is a proof, and not a weak one, of its utility in all the animals in which it is found.

It may be said that analogies are misleading, and though it may be true, that the blood of the under cava, in the fœtal calf, is split into two portions, by the projecting transversalis, or isthmus Vieusenii, it would be rash to suppose, without proof, that any thing of the kind took place in the heart of the human fœtus. In all which, we may well agree. Therefore, I solicit your attention to the following anatomical facts.

The blood of the under cava, we have seen, enters

the right auricle of the human fœtus, so as to press hard against the lower part of the septum, all the way up to the under border of the oval fossa. During the whole of this part of its journey, the fleshy wall of the auricle does not yield. After the blood has cleared the lower transversalis, and the crossings of the columnæ, which occupy the space between the lower border of the fossa, and the mouth or ending of the inferior cava, it comes to the fossa ovalis; and holding on in its course, obliquely upwards, it continues to press on the valve, which, increasing in breadth, yields, and begins to project backwards, into the left auricle, till, at last, near the upper end of the fossa, it is much broader than the foramen, and yields so much backwards towards the left auricle, that it assumes the form of a scoop. In this, the blood of the cava nearly all lodged, like a river within its banks, holds on its course, till it arrives at the upper end of the fossa ovalis,—where, finding the border of the valve not adhering, it attempts to pass through, between the front of the loose border of the valve, and the back of the tubercle, or isthmus, or thickened under border of the transversalis, or constrictor; but finding the passage too narrow, and the banks formed by the columnæ not sufficiently deep, it strikes against the upper border of the oval hole, or which is the same thing, against the lower border of the isthmus of Vieusenius; and while one part of it passes through the foramen ovale, and escapes

behind the isthmus, into the left auricle, the other is turned aside into the right auricle, where a considerable part of it, no doubt, is dashed down by the current of the upper cava pouring in.

And now, when these things are understood and attentively considered, it may be asked, whether or not it be probable that the stray particles of the blood of the upper cava that overflow the brim of the Eustachian valve, and come eddying towards the foramen ovale, while that foramen is filled and more than filled by the blood of the cava inferior, can get through? If the whole blood of the under cava is not needed in the left auricle, and cannot be received, how, if part of it is to be struck off, and turned aside into the right auricle, by the isthmus of Vieusenius, how is it possible that the blood of the upper cava, were it even coming with all its original and unimpaired momentum, could ever get to the foramen, far less get through? Or granting that it did penetrate into the stream of the under cava, how, if it did not get to its very centre, which, from its impaired momentum, it is impossible it can do, how could a drop of it arrive at, or be permitted to mingle with that part of the stream that is to go through?

I might bring forward other proofs, which, perhaps, would be more satisfactory than some that have been detailed, being grounded more obviously on the anatomy of the parts. One or two may be mentioned.

The valve of the foramen begins to appear, early in the life of the fœtus, at the bottom or lower part of the foramen, and grows up, along its sides, like the hymen; till it is gradually able to cover, or fill up the whole of the oval hole. The fleshy sides of the hole, that is to say, the transverse muscle above, and the columnæ at the sides and below, grow likewise, both in length and thickness, but they keep their relative distance from one another, so that as the child grows, so does the area of the foramen.

Both auricles are provided with a membranous lining, and it is this membranous, insensible inner coat of both, that forms the valve. The lining of the right auricle, for instance, shoots upwards and across from the fleshy edges of the hole, so does that of the left, and meeting, they cohere together; nay, they are squeezed together, by the pressure of the blood on either side; so that the valve is composed of two layers, and these are elongations of the membranous linings of both auricles, to which the foramen ovale equally belongs. A thin layer of muscular, or rather fibro-cartilaginous fibres, is sometimes found at some points between them, in the strong—in the weak, seldom.

These things being understood, and, on examination, the statement, I trust, will be found to be correct, you will see that if the streams of blood from the two cavas be mingled together, in the right auricle, and if a part of the common mass goes through

the foramen ovale, then the right auricle would be precisely like a barrel you had set on end, and had filled with water; and from which you wished to draw off a quantity by a hole in its side. Then if you had covered this hole, by pasting down over it a piece of paper, or any other material that would easily burst, the push, as you all know, would manifest itself not at the lower or upper, or at any edge of this cover, but would, by its pressure from within outwards, point, as the phrase is, at the centre, and there bursting through, the covering or valve would be left with a ragged fimbricated hole in its middle, exhibiting an appearance very like that of the tricuspidal valve at the foramen ventriculare, and like that rooted to the brim of the foramen, all around.

Now, it may be asked, is this the appearance of the valve of the foramen ovale?

We may farther ask, why, if the blood of both cavas passes through, why does the valve grow always upward, from the lower edge of the foramen?—Why does it never grow down from the upper edge? On the supposition that the blood of the under cava alone passes through, and that it strikes against the isthmus of Vieusenius, we see a reason why the membranes that form the valve do not grow from above downward. They are opposed, they are driven back, they are folded upwards behind the isthmus, and there form a bumpy swelling; whereas downwards in the very teeth of the entering current,

that is dashing up against them, they cannot possibly get leave to grow. But on the supposition that as much of the blood of the upper cava, as of the under, goes through, there should be as little of the valve seen below as above, yet it never is so.

It may be said, that the child, during the greater part of the time it is in the womb, lies generally with its head undermost; in which situation, the upper border of the foramen ovale will be the lowest, and the blood, overflowing like water at a waste sluice, must press upon, and wash the surface over which it passes, and prevent any thing from growing there—and that, of course, the valve cannot grow from above downwards. This is turning the argument quite the other way; and would be a very ingenious evasion, were it not a fact that the head of the child is frequently uppermost, during utero-gestation; in which case, if the current of the blood prevented the valve from growing down from the upper border, when the head was down, it should check the growth of the valve from the under border when the head was up,—and it should be remembered, that in cases of twins, if the head of the one be down, the head of the other, almost as invariably, is up. The fact, however, is, that be the head up or down, the valve is found always growing up from the lower edge of the foramen.

Another circumstance may be noticed, when we inject the system of the umbilical vein, and then

raise the liver and turn it over to the left, so that its right edge shall look forward, and the vena cava be a little twisted, we see the right hepatic vein entering pretty far back, almost into the posterior side of the vena cava inferior; and into this vein, or near to it, and of course almost behind the vena cava, we see the canalis communicans, or ductus venosus, entering, so that the blood which it brings must be near the posterior wall of the vein, and, of course, it must ascend up along the anterior surface of the septum, and be among the first to pass through the foramen ovale.

Taking it, then, as certain, that a part of the blood of the under cava, and of that alone, passes through the foramen from the right auricle into the left, and that this, be its quantity one-third, or one-half, or what it may, of all that the vena cava brings, and remembering that it is partly arterial, we may now go along with it, from the left auricle into the left ventricle. From that ventricle it is thrown up into the aorta ascendens; and no sooner does it arrive at the arch, than the greatest part of it takes the rout of the carotids, and the remainder turns down into the aorta descendens. The course of the blood through the axillary arteries of the fœtus in utero, from the bent position of the arms, which are squeezed to the sides, neither is, nor can be, so direct, nor so free, as that through the carotids and vertebrals; and as these are destined for the head, it might be expected that the

head and brain should, as we formerly saw was the case with the liver, manifest the effects of such an abundant supply. But as this blood, though more arterial than that which we left in the right side of the heart, is far from being so pure as that which the liver received from the umbilical vein, it cannot be expected that the brain, however much grown, should be so perfectly organized, as to render the sensibility of the fœtus very acute, or its power of muscular motion very strong. The brain of the fœtus, compared with the size of its body, is large; but its organization, even at birth, seems to be far from being perfected. The sutures of the cranium are not closed; and the head is squeezed, at times, so much out of shape during labour, that we are often astonished how the child could have endured such a degree of pressure, as could produce such an effect, and yet live. But when we consider that acute sensibility, or vigorous muscular action, would have been not only extremely inconvenient to the fœtus in utero itself, but even dangerous both to mother and child; while yet a brain, so fully grown, as to be ready gradually to act, as soon as the child was born, was necessary, we see the wisdom of furnishing blood in abundance for growth, but of keeping the sensibility low, by giving the arterial principle with a cautious and a sparing hand. As for the rest of the blood of the aorta ascendens, which is not sent up from the arch, it passes down, as has been said,

into the aorta descendens, where we shall meet with it again.

In the meantime, we may now return to that part of the blood which we left in the right auricle; the blood that was composed of all the blood poured into that auricle, by the upper cava and coronary vein, together with that part of the blood of the under cava which did not go through the foramen ovale;—all these, mingled together, pass into the right ventricle, and by the right ventricle the whole is thrown up into the pulmonary artery; which dividing, as we have seen, into three branches, sends as much blood as passes through the foramen ovale, on to the aorta descendens, by the ductus arteriosus; and then transmits the rest by the pulmonary arteries to the lungs.

When the blood of the ductus arteriosus arrives at the aorta descendens, it meets and mingles with the blood of the left side of the heart, which the arteries going up to the head could not receive. The quantity of that blood is not great; but it is more pure than that of the ductus arteriosus: for it contains some, though that must be little, of the umbilical blood, and is, of course, more pure than the blood sent to the lungs by the two pulmonary arteries.

From the aorta descendens the bronchial arteries go off to the lungs; so that the lungs receive, by the pulmonary arteries, blood that is the least arterial of all that issues from the heart, and blood from the aorta descendens by the bronchial arteries, which is a

little, and but a little, more arterial. There is something surprising in this. The lungs are the organs that are to be first used by the child. Respiration is to be its new, and thereafter its constant work; and yet we see that the quantity of arterial blood destined for the nourishment and growth of the organs by and in which this work is to be carried on, either in fœtus or adult, is so small, that we are tempted almost to believe that there is no organ in the whole machine, containing an equal quantity of matter, that receives such a scanty supply. As for the opinion, that this deficiency is compensated, in the adult at least, by respiration, it has never been proved, and could be of no use here, as the fœtus does not respire. It is contradicted, too, by the analogy of the heart, which is not left to trust to the blood that passes through it, but is supplied with arterial blood abundantly by the coronary arteries: at the same time it should be remembered, that, in respiration, the lungs are entirely passive; they do not expand by any muscular power of their own; the cavity of the thorax is enlarged by other powers, and the air enters and blows them up. The cavity is lessened also independent of them, and the air is squeezed out of them again; but, in all this, they are merely passive. Is it not probable, then, that if they had received as much arterial blood as muscular parts seem to require, their sensibility would have been too acute for the uses to which they are put; and that the continual

dilatation and compression which, like mere bladders, they are doomed unceasingly to endure, required that they should neither receive, before nor after birth, much of the arterializing principle, on which, if not the existence, at least the exercise of irritability, seems, in a great measure, to depend?

Having thus got on with the blood, in its progress from the placenta, till we have reached the aorta descendens, and seen that vessel give off the bronchial arteries, and noted the diminutive size of the intercostals, the cœliac, the mesenterics, the renals, the pelvical, and the iliac arteries, and seen the large size of the umbilicals, which seem to be the continuation of the iliac trunks, we arrive at the placenta again, from whence we set out; and considering that the intercourse between the umbilical arteries and the umbilical vein, in or through the placenta, is more free than that between the other branches of the aorta descendens, and their corresponding veins, we are not surprised to see those parts of the fœtus, to which the branches of the aorta descendens give blood, diminutive in their size, and dwarfed, as it were, for want of a plentiful supply; for we see that the blood of the aorta descendens has taken the more patent road—that of the umbilical arteries, and left the vessels which go to the other parts in a great measure drained of blood.

And here, perhaps, I should stop; but sure I am, that the number of the circumstances which have

come before us, and the variety of the ideas which have come under our review, must have left the young student, at least, not a little bewildered among the crowd of his reminiscences; which, though the advanced student may not require any such assistance, renders it imperious on me to make the whole pass, in a condensed recapitulation, before you.

The result, then, of the whole is, that as the fœtus in utero does not respire, yet cannot live, except the blood which circulates through it be regularly purified, and freed from its venous principle, and made arterial, that process must be made up to it in some other way. But as the subject of the respiration of the adult has not, as yet, been before us, nor the action of the placenta in the fœtus, we were obliged to take for granted what you will hereafter see proved; namely, that the blood sent out of the body of the fœtus, by the umbilical arteries, to the placenta, dark coloured and venous, is returned to the fœtus by the umbilical vein, florid and arterial. That this blood could not be so completely arterial as the blood which returns from the lungs to the left side of the adult heart, was noted; and reasons were given for supposing, that the degree of its arterialization was as much as the fœtus in utero required, and that more it could not endure.

With this blood we proceeded to the liver, and, after noticing the manner in which the umbilical vein divided itself there, endeavoured to point out the

effects produced, by the very particular manner in which the blood of that vein is distributed. It contributed, we saw, to the growth and dilatation of all its parts ; but, by a peculiar and unusual distribution, it secured to the left lobe a certain degree of size and development before birth, which was to be checked after birth, that the other lobe thereafter might thrive.

We followed that part of the blood of the umbilical vein which did not enter the liver, and with it arrived at the heart, along with the inferior cava, and saw the collapsed or unexpanded state of the lungs, the ductus arteriosus, and the foramen ovale.

We were fully aware, that the two auricles of the heart must be filled at one and the same time, that they might be thereby enabled to contract together ; and that the ventricles must, in their turn, receive what the contracting auricles gave, that their contraction might be sudden and simultaneous also. But as the lungs had not yet been expanded, and could not receive all the blood which the right ventricle gave, it became obvious that there should be some side passage, by which the blood, sent by the right ventricle, but which the lungs could not allow to pass, should get to the left auricle. But in the septum, between the right ventricle and the left, no such passage could be found. We were warranted, therefore, in doubting, that the transmission of the blood from the one side of the circulatory system to

the other, as in the adult, was the whole of the end which nature had in view; and we were the more convinced that there were some ulterior aim, when we saw that a part of the blood of the right auricle was sent through the foramen ovale into the left.

We examined with care, and with the respect due to the author, the theory which supposes that, in all this, the aim of nature is to form a double heart for the adult, but to use it as a single heart for the fœtus, that the blood which was to be sent out of the fœtal body to circulate through a distant organ—the placenta, might enjoy the benefit of the force of two ventricles instead of one; and we saw abundance of evidence to conclude, that, as the right auricle is less powerful than the left, this would not give strength, but impair it.

We next looked a little more narrowly at the foramen ovale, as also at the venæ cavæ, and the coronary vein, and saw that the theory which supposes the Eustachian valve to be of use only to the adult, was altogether untenable: and that the opinion which maintains that this valve is of no use whatever to the fœtus, is contradicted and overturned by a host of facts: for the wall of the auricle, we saw, was not imperfect in the adult; and that though it were, the Eustachian valve could not eke it out, for it is frequently awanting. But even supposing it always present, we saw that it could not help the wall of the auricle, whether imperfect or not, to gather the blood

of the auricle in towards the ventricular foramen; for it was evident that the valve is of such a shape and size, and is so placed, that it must lose the power which the theory ascribes to it, at the very moment when the exertion of that power could be useful; that is to say, when the auricle is contracting, and forcing the blood on. On the contrary, it appeared, that if this valve be of any use at all to the adult, that must be at the time when the auricle is filling: for whenever the auricle begins to contract, and the sluice of the foramen ventriculare to yield, and the blood to move toward the ventricle, the Eustachian valve becomes relaxed, and yielding, must fall impotent and passive before the tide.

But while the use assigned to it in the adult by this theory was seen to be ideal, and opposed by so many facts, it was noticed, that although this valve is often broken down, absorbed, and altogether away in the adult, it is always present in the fœtus; and the first part of the important service it performed to the young animal, was shewn to be the opposition which it gave to the blood of the coronary vein, attempting to get across the bottom of the auricle, and to approach and get through the foramen ovale, along with the blood of the inferior cava. It was, at the same time, observed, that the two auricles were so placed with regard to one another, that the one was situated before, and in some measure below the other, while the septum, that is common to both, was

stretched obliquely from above downward, and backward, between the two; that the current of the under cava did not set in direct into the right auricle, but somewhat obliquely upward and backward; while that of the upper cava entered the auricle from above and farther forward; so that the anterior side of the current of the under cava, if continued, would pass almost behind that of the upper cava, whereby the stream of the upper cava is directed with still greater certainty forward, against the anterior wall of the auricle, while that of the under cava holds on behind: and while the blood of the under cava comes to be in this way pointed towards the oval hole, that of the upper cava is directed away from it altogether; but being resisted and opposed by the anterior wall of the auricle, it is deflected downwards and reverberated backward, and to the right, and would have spread abroad in the lower region of the auricle, and have mingled itself with the blood of the under cava, and gone with it through the foramen ovale, had not the Eustachian valve risen up between.

It was then shewn, that this care to keep the blood of the cava superior and coronary vein from mingling with that of the under cava, was demonstrated by many other obvious, but lesser, and therefore, perhaps, hitherto unvalued facts; for, it was shewn that as the blood of the under cava was more copious than that of the upper cava, and came up unopposed into the auricle, in the very direction of the foramen

ovale, while that of the upper cava, even had no Eustachian valve stood in the way, could not have got to the foramen, but by reflexion; the blood of the under cava must go through with undiminished force, while that of the upper cava must approach with the lessened momentum of a reverberated tide. But when it is considered that the blood of the upper cava is opposed by the Eustachian valve, that no part of the blood which it brings, but that which overflows the Eustachian valve, and approaches the blood of the under cava as an eddying and spent tide, does get near to the stream of the under cava, it was seen that with that stream it cannot be permitted to mingle, but must be thrown aside.

This became more obvious, when it was considered that the whole blood of the under cava was not needed in the left auricle; that about one-third, nay more of it, is struck off by the isthmus of Vieusenius, against which the current of the under cava impinged; and that this superabundant quantity, turned aside as it must be into the right auricle, pushes before it, and still farther away from the foramen ovale, the stray particles both of the upper cava and coronary vein.

The whole was rendered more conclusive by attending to the valve of the foramen ovale. It was seen to grow from below upward, but never downward; and on the supposition that the blood of both cavas mingled in the right auricle, and passed through

the foramen ovale indiscriminately, no satisfactory answer could be given to the question, why the valve was not open in the middle, and rooted to the foramen all round the brim.

It then came to be clearly seen, that as the whole blood of the adult passes from the right auricle, through the lungs, by the pulmonary arteries, and returns to the left auricle by the pulmonary veins, a part of it only is allowed to pass, in the fœtus; and the rest is sent, not only past the lungs, but past the left auricle also, while a quantity of the blood of the under cava is carefully kept apart from that of the upper cava and coronary vein, and is sent through the foramen ovale from the right auricle into the left; and in effecting this, the services of the Eustachian valve are not only obvious, but absolutely necessary.

These things being duly considered, it became more than apparent that something more is necessary, and that something more is done, than the mere sending past the lungs a quantity of blood, which they could not receive; it became evident, that though this be one part of the aim, and a necessary and obvious one too, yet there is another, namely, the sending the blood, which the lungs could not receive, not only past the lungs, but past the left side of the heart also; and when it came to be considered, that the blood so sent past is venous, while that which is admitted into the left auricle, through the foramen ovale in its stead, is arterial, the suspicion waxed

strong, that if the venous blood had been allowed to pass through the foramen ovale, into the left auricle, some material injury would have been thereby done; and consequently, that some important and salutary end is served by the arterial blood, that is reserved and permitted to go through.

That end we distinctly saw in the growth and development of the fœtal brain, when we followed the blood of the left auricle up through the aorta ascendens. And if I thought that any doubt could yet remain with regard to this matter, I would urge the hint, lately thrown out, but on which I did not insist, and it is this, why, if merely passing the lungs were all that is necessary, why, to make the left side of the heart as full as the right, did not the ductus arteriosus terminate in the left auricle, in which case the foramen ovale would have been unnecessary?—Or, if any objection which the mere passing the lungs has not to produce, do actually exist, to such an obvious and easy method of rendering the one side of the heart simultaneously efficient with the other, it may be asked, why did not the ductus arteriosus, or the pulmonary artery itself, communicate with the aorta *ascendens*, instead of the *descendens?* The reason why neither of them do communicate with that artery cannot be, that any inconvenience would have arisen from distance, for they lie in contact with one another. It could as little be that their currents would have opposed one another, for they would

have all run the same way. No; there is not an answer to this objection, that I can find. The ductus arteriosus is neither sent to the left auricle nor to the left ventricle, nor to the aorta ascendens; for the blood it conveys would have contaminated the blood in the left auricle and aorta ascendens, which nature had separated, in the right auricle, with so much anxiety and care, to send it up to the head, for the growth and perfecting of the brain. The ductus arteriosus, therefore, with its venous blood, is sent past the left side of the heart—nay, past the arch of the aorta, and made to enter the aorta descendens, after all chance of doing harm is at an end.

The other circumstances, of lesser note, which followed, in order, and as the continuation of the chain of facts, as we traced the course of the blood from the arch of the aorta to the placenta, have been so recently before us, I need not, in this general recapitulation, go over them again. Here, therefore, we may leave this complicated piece of anatomy—this beautiful and interesting piece of physiology—and the only thing which now remains is, to see how all these peculiarities end.

Abolition of the Fœtal Peculiarities.—The scope and the design of all and every one of the peculiarities, as they are usually called, of the circulation, in the fœtus, is, we have seen, in the first place, to compensate for the want of respiration; and, 2dly, to dis-

tribute the purified blood more abundantly to some organs than to others, that they may be ready to act as soon as the child is born.

After birth, or at times during birth, the child makes a deep and gasping inspiration, and immediately, in general, or soon thereafter, all the peculiarities are done away. There is in this something so magic like, so sudden, so simple, so complete, that after we have examined and comprehended what has been done, and how it has been done, we stand astonished, and anxiously contemplate the effect. All that we see done is, that the child has opened its mouth, raised its ribs, advanced its sternum, and depressed its diaphragm; in other words, has enlarged the cavity of its thorax. The consequence of this is, that there would be a void space, a vacuum, left between the surface of the lungs and the parietes of the thorax; were it not that the air rushes down through the aspera arteria, and blows up the lungs; so that as the parietes recede, the lungs expand, and are, during the whole time of their expansion, as much in contact with the walls of the thorax, as they were before the expansion began.

There is, however, another effect which immediately follows, or rather is synchronous with this enlargement of the cavity of the thorax; and though less attended to, is perhaps of as great, if not greater importance. It is this, the same force that draws or presses the air down through the trachea, presses or

draws into the lungs, not only the blood that used to come into them by the pulmonic branches of the pulmonary artery, but all the blood that used to go past the lungs, by the ductus arteriosus.

This is a great change in the circulation; and because not seen so evidently as the entry of the air into the lungs, is more puzzling to the young student; till he recollects that all the branches of the pulmonary artery, which, before the amplification of the thorax, were crumpled up and compressed, so that they could not receive more blood than what the pulmonic branches of the pulmonary artery brought, are now stretched out and elongated, and freed from compression; and not only fill up all the interstices between the ramuli and vesicles of the bronchial tubes, but cover and hide them with a coating of capillary vascularity,—and that as these blood-vessels were as much compressed before inspiration, as the air-vessels and cells, he will see that they are now as able to receive an additional quantity of blood, as the dilated bronchial tubes are to receive an additional quantity of air. The matter may be made more intelligible still, by the following simple experiment.

Take two vessels, as nearly alike in shape and capacity as may be, and pour into the one of them a certain quantity of pure water, and into the other an equal quantity coloured; and having weighed them, take a common injecting syringe, and fit accurately to the nosle of it a tube, from which two other tubes,

as nearly equal to each other in length and diameter as possible, go off; then insert the mouth of the one for some way into the water in one of the vessels, and the other into that in the other; and drawing up the piston, and allowing time for the fluids to rise, remove the syringe with its tubes, and weigh the vessels again. It will be found, if things have been properly adjusted, that the quantity of water which has risen up through the one tube, is exactly equal to that which has risen up through the other.

These things being considered, the student will see that the vacuum which has been formed, by drawing up the piston, is precisely like the vacuum that has been formed by the enlargement of the cavity of the thorax; and he will understand how it happens that all the blood, which used to pass through the ductus arteriosus to the aorta descendens, is now irresistibly drawn into the lungs, through the two pulmonic branches of the pulmonary artery, and that these must dilate, to receive this extra tide; while, on the other hand, the ductus arteriosus, obedient to the law that obtains in all such cases, must shrink and become impervious, and, at last, be converted into a ligament.

He will also see, and that clearly, that, as now all the blood, thrown out of the right ventricle of the heart, into the pulmonary artery, circulates through the lungs, and returns to the left side of the heart, by the pulmonary veins, which pour it into the left

auricle in full streams, the valve of the foramen ovale must be pressed as firmly against the septum on the left side, as by the blood from the venæ cavæ and coronary veins on the other—and that no blood can now pass through the foramen ovale from the right auricle into the left, or from the left into the right. If the valve adhere to the septum, all around the brim of the foramen—good and well: but if it do not, as sometimes is the case, no inconvenience can ensue; for, the forces on either side being equal and opposite, the valve must stand like a door or flood-gate, shut, accurately shut, but not bolted.

It will, I fear, be more difficult to bring into view the causes that arrest the circulation in the umbilical cord.

Some have supposed that the vessels of the cord must shrink, when exposed to the cold air. But though this theory may have some appearance of reality in cold climates, it will not explain the fact in the torrid zone.

Others have had recourse to atmospheric pressure, &c., and with equal success. There seems to be very little reason to hope for an explanation of the fact, from any thing external to the child. We must, then, look within. And here it should be remembered, that the heart of the child that has respired, is double; so long as the ductus arteriosus was pervious, and the foramen ovale open, the heart was single. But now that they are both shut, and the one side of the heart

has no communication with the other, all the blood passes through the lungs, and is there rendered arterial, and is returned to the left side of the heart a more powerful stimulus than it was before. And, in the next place, it should be remembered, that before the child respired, the blood, in the ductus arteriosus, was sent into the aorta descendens, by the force of the feeble right ventricle; but after the child has respired, the whole blood is thrown into the aorta ascendens by the more powerful contraction of the left ventricle. The consequence of this immediately is, that the push made against all the branches of the aorta, and against the diminutive branches of the chylopoietic viscera among the rest, is greatly increased; and they must, and do dilate, and receive a greater quantity of blood.

But if a greater quantity of blood be sent, and with an increased momentum, into the dilated chylopoietic arteries, a greater quantity must be returned to the vena porta, by the abdominal or chylopoietic veins. Let it now be recollected, that in the fœtus the largest branch, (*f*, *fig.* 12.) of the umbilical vein, entered into the vena portarum, and that the blood which it brought, circulated throughout the liver in the hepatic branches of the vena portarum, because the quantity of blood, in the vena portarum, was small, and its momentum less than that of the blood in the umbilical vein. But the child having respired, things are greatly altered. The quantity of blood that is brought to

the vena portarum, by the ventral veins, is much increased, and its momentum is greatly augmented; so that when it arrives at the communicating branch (*f*, *fig.* 12), it drives back the blood in that branch, and thereby arrests the progress of the blood in the umbilical vein, all the way back to the extremities of the arteries in the placenta. But if now no blood can enter the child by the umbilical vein, and if as little can go out of it by the umbilical arteries, these arteries will, like the ductus arteriosus, shrink and become impervious ligaments, all the way back to the last branches they gave off, at the sides of the bladder, while the vein will be converted into a ligament, and ever after serve only to strengthen the lower border of the suspensary ligament of the liver.

But, if the foramen ovale be closed, and the ductus arteriosus and umbilical cord be converted into ligaments, the heart is no longer the single heart of the fœtus, but the double heart of the respiring child,—all the peculiarities are done away, and the permanent order of things is established.

It should follow as a corollary, from much that has been said, that if arterial blood, as is generally supposed, be a stronger stimulus than venous blood; and if the irritability of a part be in proportion to the vitality of the blood by which it is fed; then, so long

as the child is in the womb, and without respiring, the action of its heart should be slow and feeble. This conclusion has been countenanced by an observation, made some years ago, by my friend Dr. M'Donnel of Belfast, who, in a case of turning, accidentally got hold of the cord; and improving the opportunity, ascertained that the pulsation in it was slow,—which observation, then unexpected, he afterwards verified in the cow. In this opinion, so far as the pulsation in the cord is concerned, I know he perseveres; though, having made himself familiar with the use of the stethoscope, he agrees, I learn, with those who, by the application of that instrument to the outer surface of the abdomen of the gravid female, have been led to believe, that the pulsation of the heart of the fœtus, in utero, is quick. The matter, most assuredly, will not be permitted to rest here; and it will not surprise me, if both observations be found to be correct; for, it is probable not only that the different pulsations depend on different causes, but that the pulsation of the fœtal heart is indicated by that of the cord.

It might be stated, and perhaps should have been stated, as a fœtal peculiarity, that the blood circulates through the lungs of the fœtus, by the force of the heart alone; whereas, after the child is born, there seems to be no less than three powers engaged in rendering its transit secure and certain. The first of these, no doubt, is the projectile force

of the right ventricle, aided, as some would say, by the elastic expansile power of the left auricle. The second is the inspiratory dilatation of the lungs; whereby the blood not only of the two pulmonic branches of the pulmonary artery, but the blood that used to go past the lungs by the ductus arteriosus, is drawn into, and forced to go through the lungs, by the expansion of the cavity of the thorax; and, thirdly, however unfashionable the old doctrine may be, I think it more than probable that the pressure which, during expiration, the lungs are forced to endure, contributes in no small degree to urge the blood in the lungs on, and prevent engorgement.

THE END.

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f, Where coronary vein should have been.
h h, Root of tricuspidal valve.
g, Musculi pectinati turned down.

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Fig. 3.

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ERRATA.

Page 18, line 23, for *from*, read *to form*.

— 69, line 20, for *aorta*, read *placenta*.

FIGURE 1ST

James Harvey del.

Miller lithog

FIGURE 2?

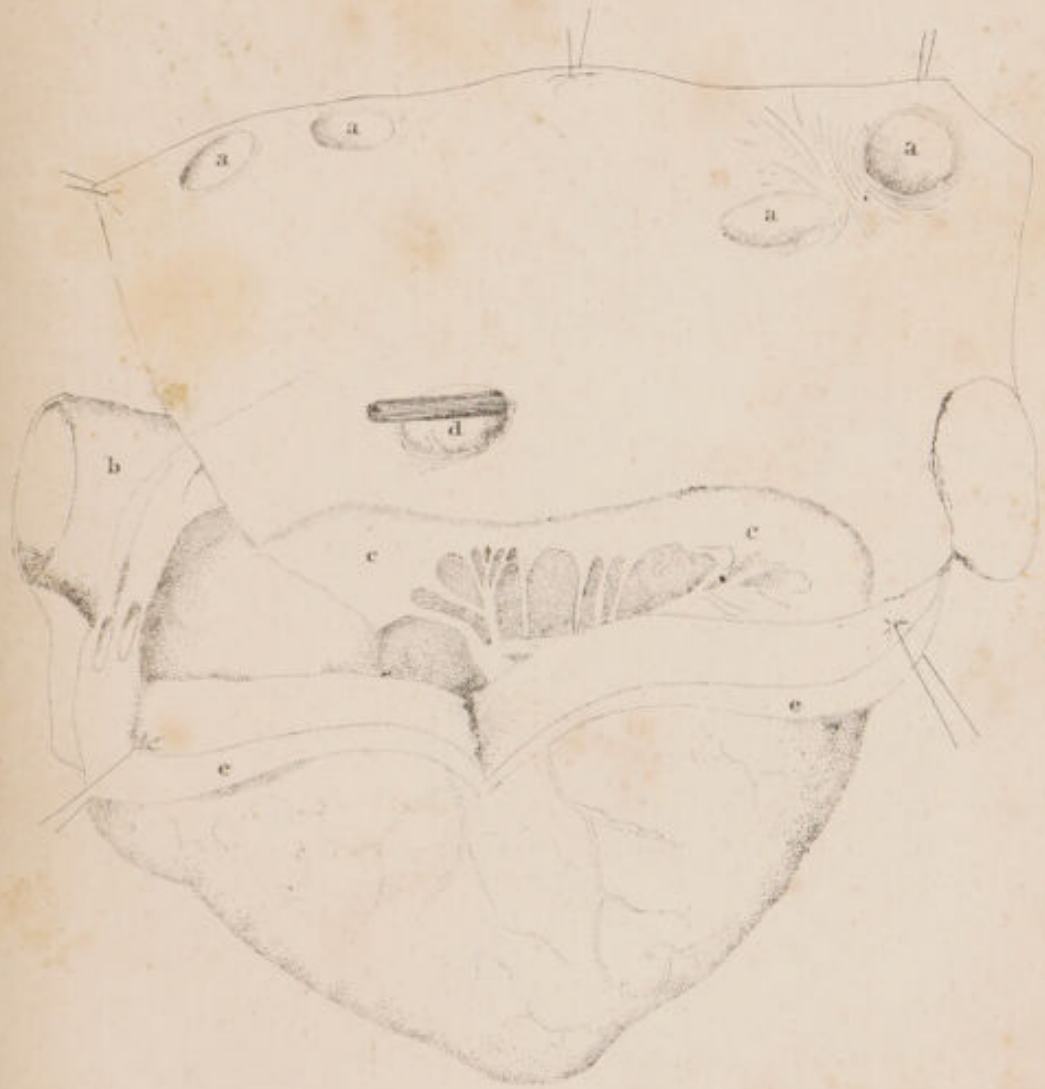
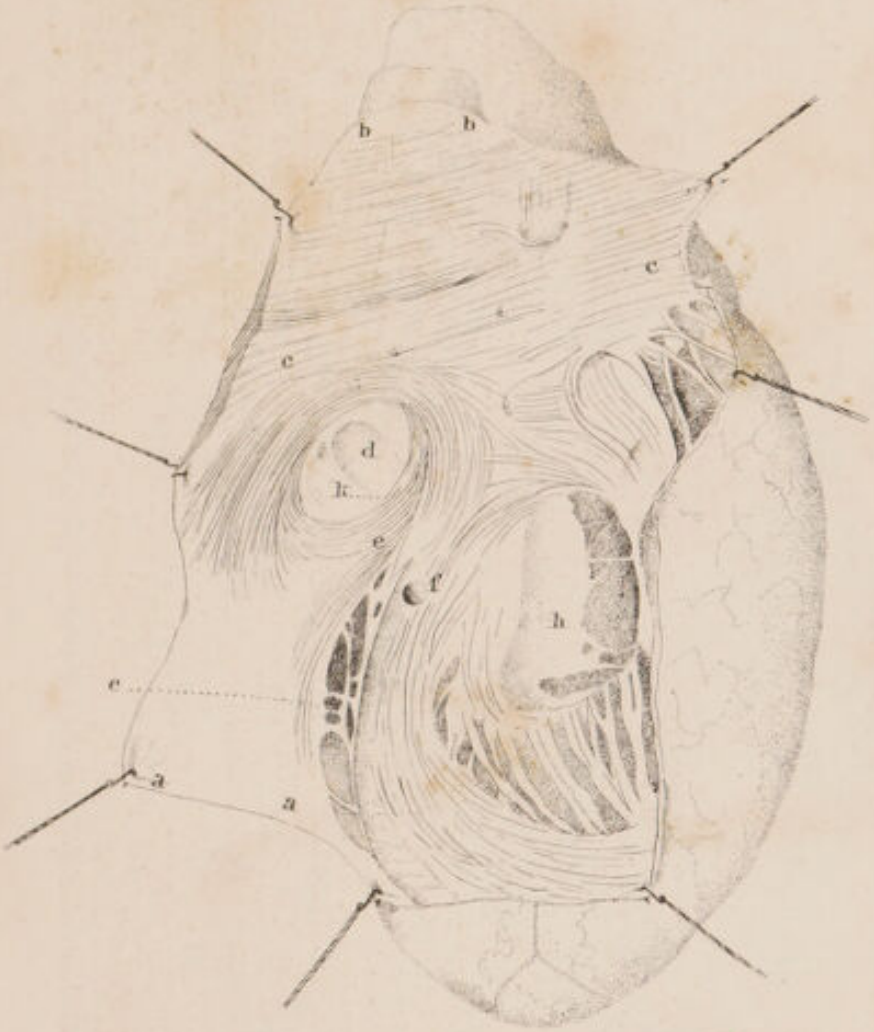


FIGURE 3ª



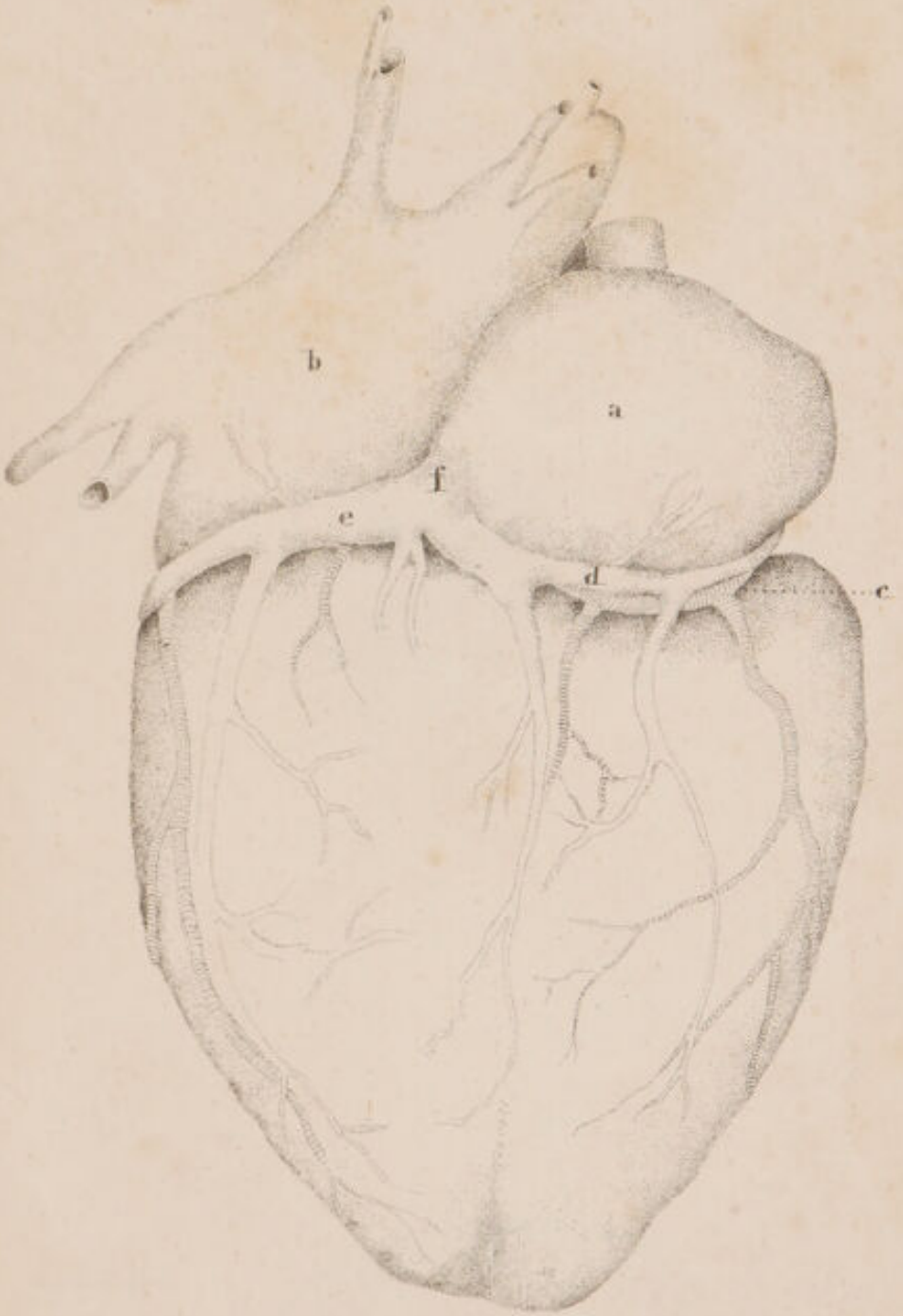
James Harvey dr.t *Miller lithog*

FIGURE 4th

James Harvey. Delt

Miller. Lithog

FIGURE 5TH.



James Harvey Del.

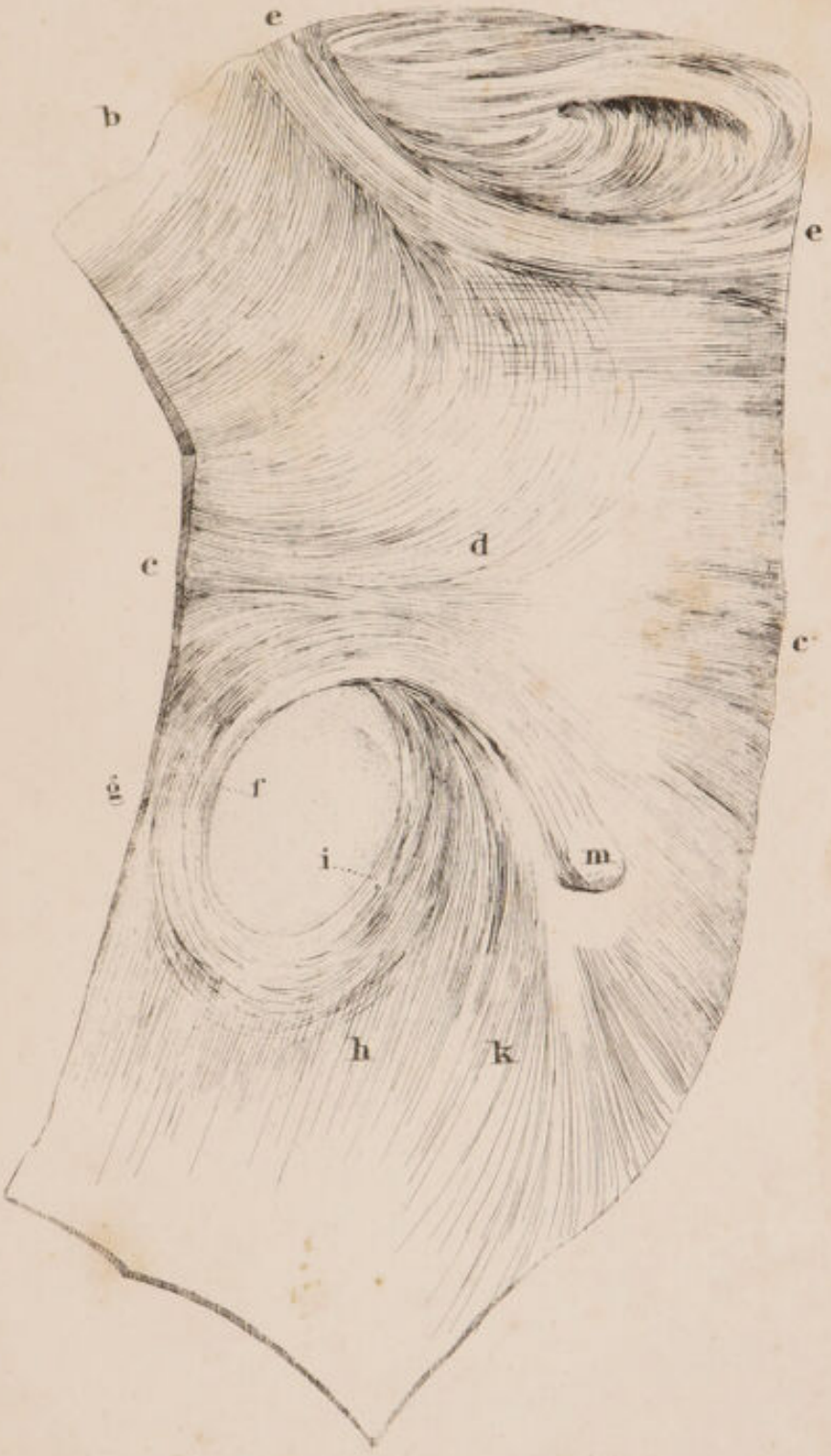
Miller Lithog.

FIGURE 6TH.

Ja.s Harvey delt.

Miller Lithog.

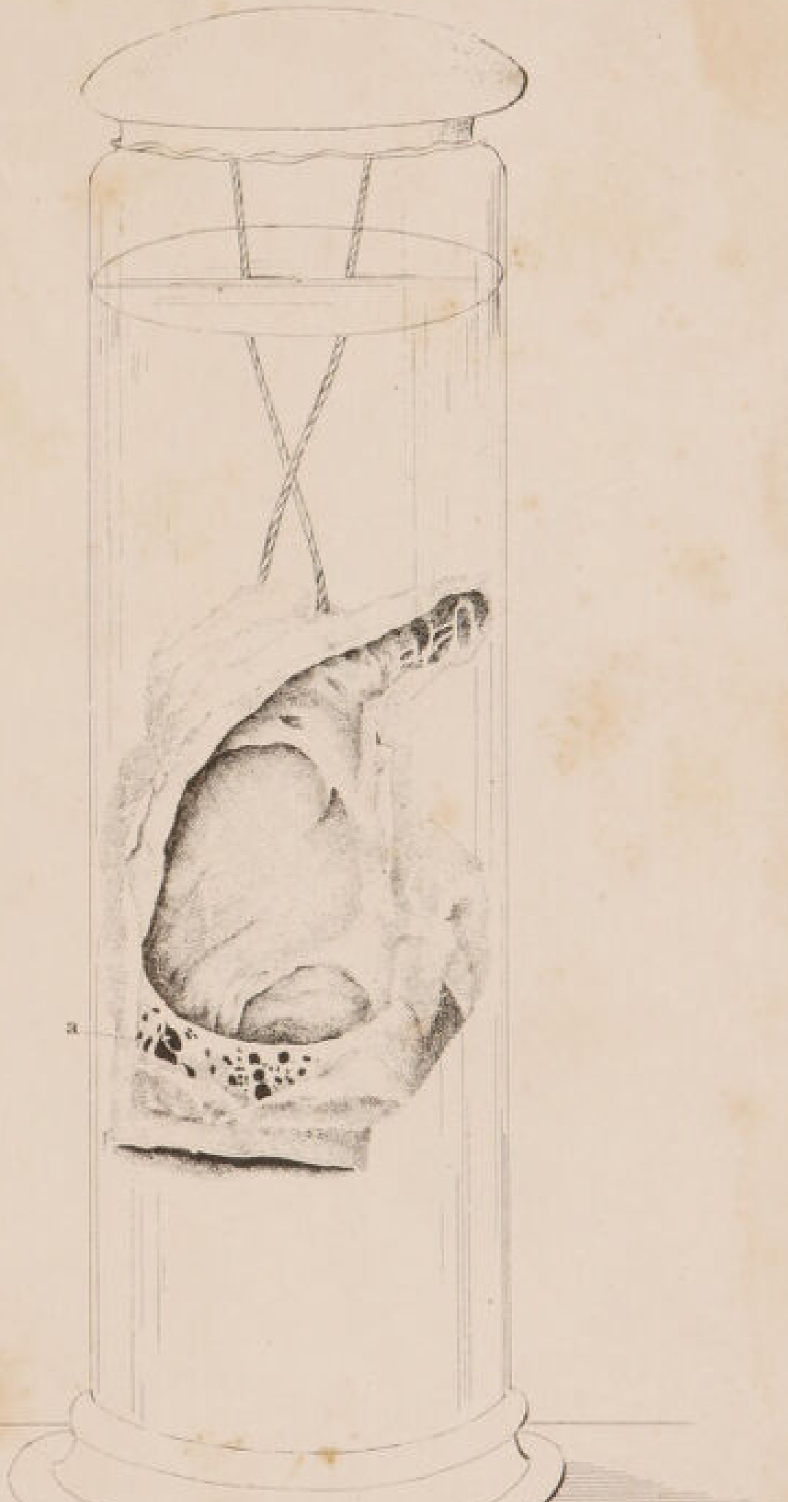
FIGURE 7TH



R. Carswell Del.

Miller lithog.

FIGURE 8TH.



R. Cresswell del^t   Muller lithog.

FIGURE 9TH.

R. Carswell Del.

Miller lith.

FIGURE 10TH

R. Carswell del.

Miller lithog

FIGURE IIde

R. Carswell del.

Miller lithog.

FIGURE 12TH.

James Harvey del.

Miller sculp.

FIGURES 13 & 14.

James Harvey del.

Miller lithog

FIGURES 15 & 16.

Right side.

Left side.

James Harvey del.

Muller lithog.

FIGURE 17TH