

**On the action of the heart, and a case of congenital fissure of the sternum
(a) / by F.W. Pavy.**

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ON THE ACTION OF THE HEART,

AND A CASE OF

CONGENITAL FISSURE OF THE STERNUM. (a)

BY F. W. PAVY, M.D.

I HAVE now, Gentlemen, to speak about the action of the heart, and, as I have told you, I propose to show you how it beats in an animal where the chest has been opened and the respiration is artificially maintained; and afterwards to compare what we thus observe with what may be seen through the soft parietes of the chest, in the case of a foriegner now visiting our country, where nature has supplied us with an unusual exposure of this organ, by an arrest of development of the chest-bone. By such a mode of treating our subject, I may inform you at once that we shall have to differ considerably from the description you may have read of the heart's action in our ordinary works on Physiology.

In the action of this organ, as you will presently see for yourselves, the corresponding cavities of the two sides accompany each other in contracting and dilating. But little force is demanded of the auricles, whilst great strength is required of the ventricles, as they have to overcome considerable resistance, and form a most important consideration in maintaining the circulation. It must not, however, be overlooked that the action of the heart is not the only force in operation for keeping up the current of blood in the animal body. Plants have no hearts, and yet there is a circulation of their juices, in obedience to a definite arrangement. In some of the lower animals there is a circulation without the development of any special propelling organ to maintain it; and even in the embryonic condition of the highest, a definite movement of blood takes place before the heart is sufficiently developed to occasion it. What force is there, then, in these cases to establish a current, and what is there that causes the blood to move (as we may easily satisfy ourselves it does by the aid of the microscope, in the web of a frog's foot, after the animal's

(a) From the Lectures on Physiology delivered at Guy's Hospital.

heart has been excised? It has been styled the capillary force, and we regard it as arising from an attraction set up by the nutritive changes taking place between the issues on the one hand, and a fresh supply of nutritive fluid on the other. There can be no doubt that this forms an important item in aiding the circulation of blood in our bodies; but our life is so intimately dependent on an exalted functional activity of our nervo-muscular apparatus, which requires a rapid renewal of the nutritive current, that an additional force is rendered necessary, the operation of which is indispensable in maintaining the circulation at the requisite degree of activity. Hence, when this additional force—the action of the heart—fails, a rapid arrest of the circulation ensues, which is an equivalent expression to death.

If you consult your text-books on Physiology, you will find the description of the action of the heart to be somewhat in these terms:—"The corresponding cavities of the two sides act simultaneously, while the auricles and ventricles respectively contract and dilate alternately. The ventricles are continuously engaged in contracting and dilating, and occupy an equal period of time in each. The auricles, however, not only dilate during the whole of the ventricular contraction, but continue dilating during the first stage of the ventricular diastole, and do not contract until its second stage, thus leaving a period in the heart's action when all its cavities are alike undergoing dilatation." This, I say, is the description that is given you of the action of the heart in the mammal as well as in the reptile. Let us put it to the test of observation, in order that we may judge for ourselves about its accuracy.

I will expose the heart of a frog without disturbing its connexion with the vessels derived from it. You see it still beats with force and regularity, and strictly in accordance with the above description. The contraction of the auricles is sharp and almost instantaneous, and *immediately* precedes—so much so that the one seems to run into the other—the contraction of the ventricle, which is gradual and prolonged.

In this tortoise I have removed a square piece of its hard investing case, and on opening the pericardium, the action of the heart is most beautifully displayed. The successive stages will be more perceptible to you than in the case of the frog, on account of the much larger size of the animal. The ventricle appears to take its time in contracting, and gradually distends the large vessels derived from it, while the action of the auricles is sudden and forcible; visibly emptying themselves completely at each contraction.

Those at a distance may satisfy themselves after lecture that what I have stated is correct. But, although true for the reptilian heart, yet I have strong reason to assert that it is far from an expression of the truth for the mammalian heart. The results of my own observation, not in one, but in, now, a considerable number of instances where I have exposed the mammalian heart, and kept up artificial respiration, compel me to reject altogether the preceding description as a statement of its action. It seems to me that this description, which we find in all our standard physiological works, must have been taken from what is observed upon the reptilian heart, and the inference drawn, that the heart of the mammal acted in a corresponding way.

The action of the heart is so intimately dependent upon the normal performance of the respiratory function, that I must tell you objection may be taken to what we see in the exposed heart of the mammal being accepted

as a statement of what occurs in the unmutilated animal. In the frog and tortoise we can expose the heart without in the slightest degree interfering with the function of respiration, because these creatures force the air into their lungs by a process analogous to deglutition. But, in the mammal, it is far otherwise. In this animal the thorough exposure of the heart necessitates an interference with the respiration, which has to be maintained artificially if we wish the circulation to be kept up. To those, however, who have repeated the experiment several times, it is soon apparent when the heart is acting regularly and normally or not; and *what I have observed upon the dog is corroborated by what is seen upon this person whom I shall presently refer to, where nature has supplied us with an unusual opportunity of partially witnessing the action of the human heart.* In the individual in question, the heart is admitted, by all the auscultators who have examined him, to be in a perfectly healthy condition. We may therefore, I consider, look with confidence upon our conclusions if what we observe upon him tallies with what we observe upon the exposed heart of the dog.

I will perform the experiment before you, so that you may all have an opportunity of witnessing the movements of this organ, which commence a considerable time prior to birth and continue incessantly till death. We suddenly destroy the medulla oblongata and the brain of a dog with this instrument, specially constructed for the purpose. We have now an end of all sensation. The respiration is instantly arrested, and the heart would quickly cease to beat if we allowed the animal to remain in this condition. We expose the trachea, and with all the speed possible, firmly ligature a canula into it, which is connected by tubing with a pair of bellows, so that artificial respiration may be performed. The heart may be felt through the chest beating rapidly, feebly, and irregularly, but on inflating the lungs a few times, its action becomes subdued and natural. On freely exposing the interior of the chest by dividing the costal cartilages and raising the sternum, the heart is surrounded by the pericardium, which has to be opened to display the organ. The lungs are alternately rising and falling through the action of the bellows, and the heart is pulsating with vigour and regularity.

On now attentively observing what takes place, we notice the apex of the heart somewhat tilted forward during contraction and partially turned upon its axis in the direction from left to right anteriorly. The action of the ventricles is sharp and rapid, instead of prolonged as in the case of the reptile. The right appears the most distended side of the heart; but nevertheless, the ventricle seems to empty or nearly empty itself at each contraction. *The right auricle never empties itself; indeed, with the exception of the appendix, which is but a very small portion of it, it looks like a large sinus, or a bulging between the two cavæ, with no more power of emptying itself than either of these veins.*

With the contraction of the right ventricle there is a sudden pulsation of the auricle, or a distinct impulse communicated to it; seemingly to me, from the segments of the tricuspid valve being rapidly thrown into the axis of the auriculo-ventricular opening, and thereby acting on the blood behind them, so as an impression like that of a pulsation to the walls of the auricular cavity. Mr. King—formerly curator of our Museum—many years ago pointed out the fact, that under over-distension of the ventricle, the tricuspid valve would allow of a reflux of blood to take place and occasion the venous pulse, which is frequently observed in cases of pulmonary disease. He also considered that the same explanation held good for the venous pulse that is observed in health, though in a less striking degree. Now, need we look—certainly in the latter condition—to an imperfect action of the valves? Would not the impulse to the contents of the auricle occasioned by the segments of the valve being suddenly thrown

into the axis of the large auriculo-ventricular opening be sufficient to account for the slight venous pulse that may be observed in health? However this may be, it is certain that in the exposed heart of our dog, the right auricle receives a distinct impulse upon the contraction of the ventricle, and just at this moment is its greatest point of distension. On looking at the chest, also, of the person before us with fissured sternum, there is a pulsating tumour, which unquestionably in my own mind is formed by the right auricle, and this receives a marked and sudden impulse upon the contraction of the ventricle; produced, I believe, not by any imperfect performance of the valves, but by their being suddenly raised into the axis of the auriculo-ventricular opening, and so acting on the blood behind them as to produce a pulsating impression synchronous with the ventricular systole.

We are told that the contraction of the ventricles occupies half the period of a single action of the heart, and their dilatation the other half; that when the ventricles are contracting the auricles are dilating, and that these continue still dilating during the commencement of the ventricular diastole, and do not contract until near its termination; so as to leave a period when auricles and ventricles are simultaneously dilating. As I have said, this is perfectly true of the heart of the tortoise and the frog; but I will leave you to determine if such a description can be accepted for the heart of the mammal, after examining its movements in the dog and in the individual before us.

In the dog the contraction of the ventricles is sharp and rapid instead of prolonged as in the reptile, and does not appear to occupy nearly so much time as half the period of the heart's action. The ventricular contraction communicates a sudden impulse to the auricles, occasioning in them a distinct pulsation, which is instantly followed by a peculiar thrill, wave, or vermicular movement, running through the auricular parietes, down towards the ventricle. This thrill or wave is coincident with the passage of the blood from the auricle into the ventricle, and takes place so instantaneously after the ventricular contraction, that the one movement appears to run or to continue itself into the other. There is then a pause which seems comparatively of considerable duration, and which is succeeded by a re-commencement of the heart's action, beginning with the ventricular contraction.

Such, then, is what we observe upon the mammalian heart whilst beating with vigour and regularity: and you perceive that the contraction of the auricle instantaneously succeeds that of the ventricle, whilst, as we have noticed in the reptile, the auricle continues dilating after the ventricular systole is over—during the first half, in fact, of its diastole. Between the auricles and the ventricles of the frog there is a distinct alternating movement, whilst in the heart before us there seems one movement, which is of a rapid and continuous character, commencing with the contraction of the ventricle and terminating with the thrill through the walls of the auricle. Beyond this thrill—when the heart is beating regularly—I can discover no contraction of the auricle; the blood appears to flow simultaneously with it through the auriculo-ventricular opening, and the ventricle to be then at once distended in proportion to the tension existing in the auricles and larger veins. In this state the heart remains until a fresh contraction of the ventricle ensues. If the two *cavæ* be held or pinched so as to prevent the flow of blood to the heart, the walls of the right ventricle are thrown into wrinkles or folds during the diastole. When the heart begins to lose its power, and ceases to perform its natural action, there may be noticed in the auricles, for a considerable time, a series of sudden, feeble, and irregular jerks.

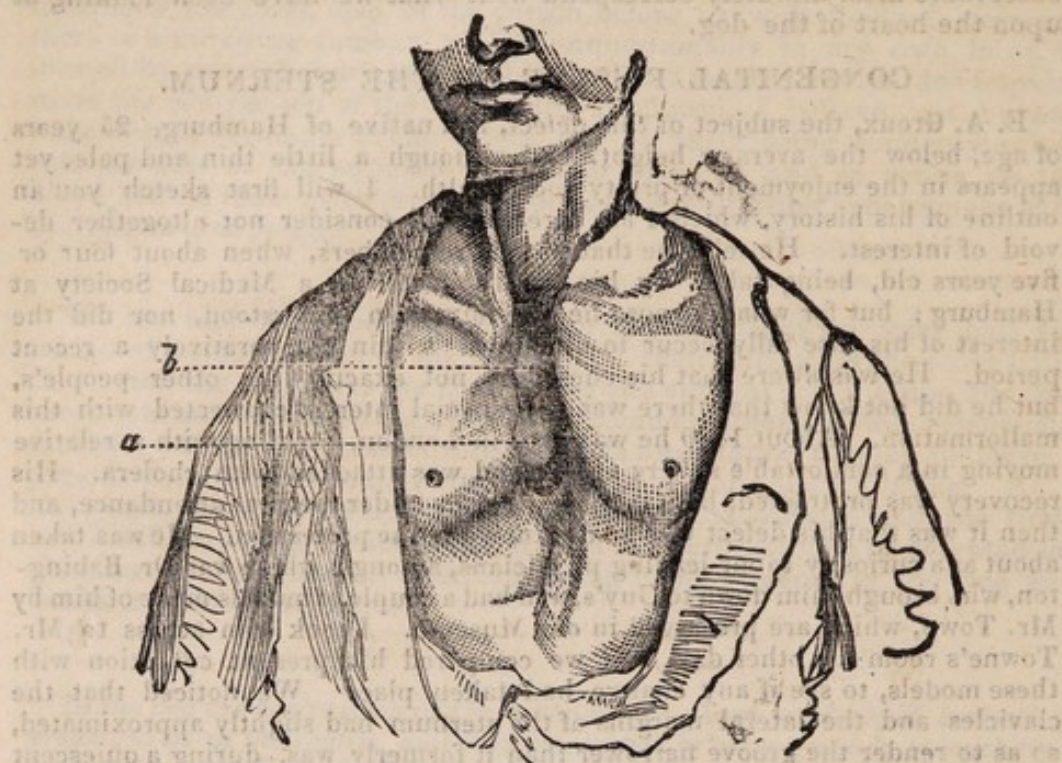
Let us now turn our attention to what we can learn from an examination of the person with fissured sternum. In running through the principal features of interest in his case, when I come to speak of a pulsatile swelling corresponding to the right auricle, you will notice that the phenomena here observable most minutely correspond with what we have been looking at upon the heart of the dog.

CONGENITAL FISSURE OF THE STERNUM.

E. A. Groux, the subject of this defect, is a native of Hamburg, 25 years of age, below the average height, and although a little thin and pale, yet appears in the enjoyment of pretty good health. I will first sketch you an outline of his history, which I am sure you will consider not altogether devoid of interest. He tells me that he just remembers, when about four or five years old, being taken by his family doctor to a Medical Society at Hamburg; but for what purpose he scarcely then understood, nor did the interest of his case fully occur to him until within comparatively a recent period. He was aware that his chest was not exactly like other people's, but he did not know that there was any special interest connected with this malformation. About 1850 he was over in London, residing with a relative moving in a comfortable sphere of life, and was attacked with cholera. His recovery was protracted, he was for some time under medical attendance, and then it was that his defect was made known to the profession. He was taken about as a curiosity to our leading physicians, amongst whom was Dr. Babington, who brought him down to Guy's, and had a couple of models made of him by Mr. Town, which are preserved in our Museum. I took him across to Mr. Towne's room the other day, and we compared his present condition with these models, to see if any change had taken place. We noticed that the clavicles and the lateral margins of the sternum had slightly approximated, so as to render the groove narrower than it formerly was, during a quiescent condition of the chest. To proceed with our sketch. He afterwards returned to Hamburg, and being seized with an attack of hæmoptysis he was recommended to leave the situation he held in a house of business which kept him confined all day, and to go into the country for a time. It now occurred to him to put in practice the suggestion, which, he says, had often been made to him, viz.:—to travel, and show himself to the medical celebrities of the different countries. Starting for Hanover in 1851, he found his expectations realized; and since then he has been visiting all the principal places on the Continent, including France, Germany, Belgium, Holland, Spain and Russia, and to judge from his appearance, one would certainly conclude that he made it thoroughly answer his purpose. He was in London for a short time, about two years ago, and after a short stay now, he intends to proceed to the provincial towns where medical schools are attached, and then to Scotland and Ireland. He carries with him an album, in which he gets one to insert one's opinion of his case and to sign one's name. So that, having been to nearly all the most distinguished men of our age, his album presents a most interesting collection of autographs, and at the same time testifies the interest his case has elicited.

On getting him to expose his chest, we notice in the medium line a longitudinal groove, which is represented in this drawing that I requested our artist to make of him. The groove of course corresponds to the absent portion of the sternum. It is bounded on either side by a continuous hard ridge, which constitutes the lateral margin of the bone, and articulates with the costal cartilages. The skin passes naturally over the chest from one side to the other, but we see it raised on one part of the groove by a pulsatile swelling (*a* in the sketch), which occupies the position of the right auricle. The clavicles and the two margins of the sternum above have no connexion whatever with each other; but below, the latter are joined by a hardish substance which holds the situation of the ensiform cartilage, and forms the lower boundary of the groove. The substance, however, must essentially differ in structure from cartilage, for it possess such elasticity as to allow him

under the influence of the pectoral muscles, when the upper extremities are fixed to open the groove to an extent of very nearly three inches; it being only a little more than half this width, at its widest part, which is opposite the third and fourth ribs, when the parts are in a natural state. By approximating



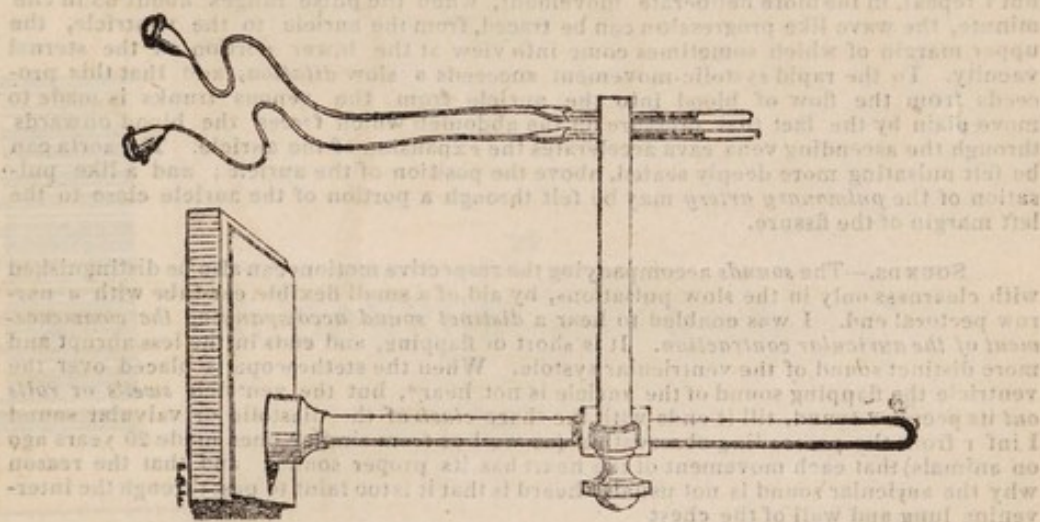
the arms the end of one clavicle may be made to overlap the other. The muscles of the neck have their normal attachments, although it seems when he takes a deep inspiration, from the cutaneous fold that is produced, as if the sternohiod and -thyroid muscles of the right side of the neck crossed over to be attached to the left piece of the sternum. But if these muscles be called into action by the process of swallowing, they may be seen to pass down to be attached on their proper side. If he be requested to cough the right lung suddenly protrudes from the chest through the groove, and ascends a considerable distance above the right clavicle into the neck.

The great point of interest, I conceive, connected with this case, is the exposure of the action of a portion of the heart, which is normally hidden from our view. We know well enough: upon examining our own bodies, the exact moment the ventricles are contracting, from the shock communicated to the thoracic parietes: but we have nothing similarly to guide us with regard to the auricles. A case, therefore, in which the action of an auricle is to be witnessed cannot fail to merit our deepest interest and attention. Now on looking at the groove a pulsatile swelling is discernable opposite the third and fourth ribs (*a* in the accompanying sketch). In its ordinary state it scarcely forms a projection except at the moment of pulsation, but if the respiration be suspended it rapidly rises to an enormous extent, measuring then even three inches from above to below, and remains full and tense until the breathing is restored, when it soon subsides. *The tumour distinctly pulsates with the contraction of the ventricle and the production of the first ing from above to below, which I have pointed out, as, at this period of the heart's action, running through the parietes of the auricle of the dog. It then sound of the heart. It rises rapidly and suddenly, and instantaneously afterwards falls with that peculiar thrill, wave or vermicular movement proceeds remains at rest until again distended by a fresh contraction of the ventricle.* From the behaviour of this pulsatile swelling, so precisely corresponding to the action of the auricle in the dog, there is not a shadow of doubt in my

own mind of its being formed by this portion of the heart: its position, however, would also lead us to a similar conclusion. You will perceive, therefore, admitting such, how this case corroborates what I have stated about the action of the mammalian heart (the contraction of the auricle immediately following, instead of preceding that of the ventricle), and stands in opposition to what we are ordinarily taught.

Between the clavicles (at *b* in the sketch) there is another pulsatile swelling, which can be scarcely seen, but may be easily felt. It is doubtless formed by the arch of the aorta, and when the fingers are placed on it, a double shock synchronous with the distension and the recoil of the vessel, or the opening and the closure of the semilunar valves is perceived.

By means of an apparatus of this description (represented in the accompanying wood cut), which may easily be constructed in the laboratory, an exact comparison can be made of the period of the impulse of the heart with the pulsation of the arteries. It is filled with a coloured liquid, and consists of a capillary glass tube, connected by vulcanised tubing with a kind of elongated funnel tied over at its mouth with a piece of caoutchouc. The slightest impression on the caoutchouc causes a movement of the fluid in the capillary tube. Applied to this person, we see that the impulse of the heart is synchronous with the elevation of the auricular



swelling; that the shock of the heart against the chest is over by the time the artery of the wrist pulsates, and is distinctly in advance of the pulsation carotid; that there is even a slight difference of time between the pulsation of the carotid and the radial: and that the impulse of the heart occurs slightly before the rising of the swelling formed by the aorta.

Extracts from M. GROUX'S Album, No. ii, 1857.

We have to day again examined M. Groux, and have found no reason to alter the opinion formed by us in July, 1855, that the alternate dilation and contraction observable between the separate portions of the sternum are mainly due to the diastole and systole of the right ventricle. The right auricle lying to the right and somewhat above the main pulsating body.

London, Nov 10th, 1857.

WILLIAM BAYLEY, M.D.
JAMES PAGET.

We have carefully examined the phenomena presented in the case of M. Groux, and have formed the opinion that the pulsating tumour, is constituted by the right auricle above and the right ventricle below, between which, in some positions of the body and in some states of respiration, a line of separation seems to be traceable.

We have derived great assistance and exactitude in our observations by the use of Dr. Scott Alison's sphygmoscope.

WILLIAM BALEY.
J. JOHNSON.
R. PAYNE COTTON.
S. SCOTT ALISON.
H. H. SALTER.

JOHN SNOW.
RICHARD QUAIN.
W. O. MARKHAM.
EDWARD SMITH.
THOMAS HAWKSLEY.

I have this day again, though rather cursorily, examined M. Groux. I am still of opinion (as I expressed in *Pasciculus* iii. of my *Medical Anatomy*, col. 36), that the pulsating tumour at the upper part of the fissure in the aorta, and that during respiration the aorta alone is felt, but that during a prolonged respiration the right auricle ascends, and that it is then seen to dilate during the ventricular systole, to contract during the ventricular diastole; in fact that then the aorta may be felt pulsating at the upper part of the fissure moving upward and downward, and that the right auricle may be seen at the lower part of the fissure moving from right to left and *vice versa*.

When M. Groux lies on the right side I consider that the pulmonary artery presents itself pulsating at the left side of the tumour two thirds of the fissure: when he lies on the left side I conceive that the right auricle presents itself to a greater extent than when he stands.

FRANCIS SIBSON, M.D.

Brook Street, Nov. 17th, 1857.

Having had another opportunity of examining M. Groux, after an interval of two years, I have been able to verify my former observations, and have also noticed some other points of interest respecting the motions and sounds of the heart.

MOTIONS.—That the *visible pulsations* in the middle third of the sternal vacuity is chiefly seated in the *right auricle* appears to me obvious from its resemblance to the same motion observed in the exposed heart of the ass; and from the fact distinctly perceptible in slow pulsations, that this motion immediately precedes the ventricular systole, the wave of motion beginning with the auricle and rapidly passing downwards to the ventricle. In quick pulsations the motion of the auricle as felt in the sternal space and the systole of the ventricle as felt and heard in its region, seem to be synchronous, but I repeat, in the more deliberate movement, when the pulse ranges about 65 in the minute, the wave like progression can be traced, from the auricle to the ventricle, the upper margin of which sometimes come into view at the lower portion of the sternal vacuity. To the rapid systolic movement succeeds a slow *dilation*, and that this proceeds from the flow of blood into the auricle from the venous trunks is made to move plain by the fact that pressure on the abdomen which forces the blood onwards through the ascending vena cava accelerates the expansion of the auricle. The aorta can be felt pulsating more deeply seated, above the position of the auricle; and a like pulsation of the *pulmonary artery* may be felt through a portion of the auricle close to the left margin of the fissure.

SOUNDS.—The *sounds* accompanying the respective motions can also be distinguished with clearness only in the slow pulsations, by aid of a small flexible ear-tube with a narrow pectoral end. I was enabled to hear a *distinct sound accompanying the commencement of the auricular contraction*. It is short or flapping, and ends in the less abrupt and more distinct sound of the ventricular systole. When the stethoscope is placed over the ventricle the flapping sound of the auricle is not heard, but the ventricle *swells or rolls out* its peculiar sound, till it ends with the sharp *clack* of the diastolic or valvular sound I infer from the preceding observation (as well as from similar ones made 20 years ago on animals) that each movement of the heart has its proper sound; and that the reason why the auricular sound is not usually heard is that it is too faint to pass through the intervening lung and wall of the chest.

The *chistole valvular* or second sound is remarkable for its clearness and loudness in this case, and on one occasion I found it reduplicated or double, and I had the opportunity of verifying the explanation which I gave of this double diastolic sound more than 20 years ago. When the end of the stethoscope is placed over the aorta, above the auricle, the diastolic sound was simple; but on carrying the instrument a little downward and to the left, so as to cover a part of the pulmonary artery the sound became double:—the whole heart sounds being expressed by the syllables *tubb-durru* instead of *tubb-dup* as usual—obviously from the two sets of valves closing in succession, not simultaneously; this want of coincidence in the closure of the aorta or pulmonary valve is only occasional, but, as it often presents itself as a phenomenon of disease, it is satisfactory to be able thus to trace its cause.

The only remaining observation which I have to record is that of a short rasping murmur heard in the course of the right carotid artery, and which must be produced there as it is not audible in the aorta, or over the course of the innominate.

49, Upper Brook Street, London, Nov. 18th, 1857.

C. B. WILLIAMS.

M. Groux having with great complaisance permitted me to spend some time in quietly examining his chest after the conclusion of this meeting, I wish to direct the attention of other observers to a point which (*I think*) may from time to time be demonstrated, viz.—that on pressing firmly with the end of the stethoscope against the apex of the right lung, within the sternal fissure, the inspiratory murmurs may be rendered more prolonged and wavy, and the expiratory murmurs more audible and prolonged.

C. RADCLIFFE HALL.

Plymouth, Torquay, December, 1st, 1857.