Notice of M.E. Groux's case of congenital fissure of the sternum, with observations of the position and actions of the heart / by Prof. Allen Thomson, M.D.

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OF

CONGENITAL FISSURE OF THE STERNUM,

WITH OBSERVATIONS ON THE

POSITION AND ACTIONS OF THE HEART.

BY

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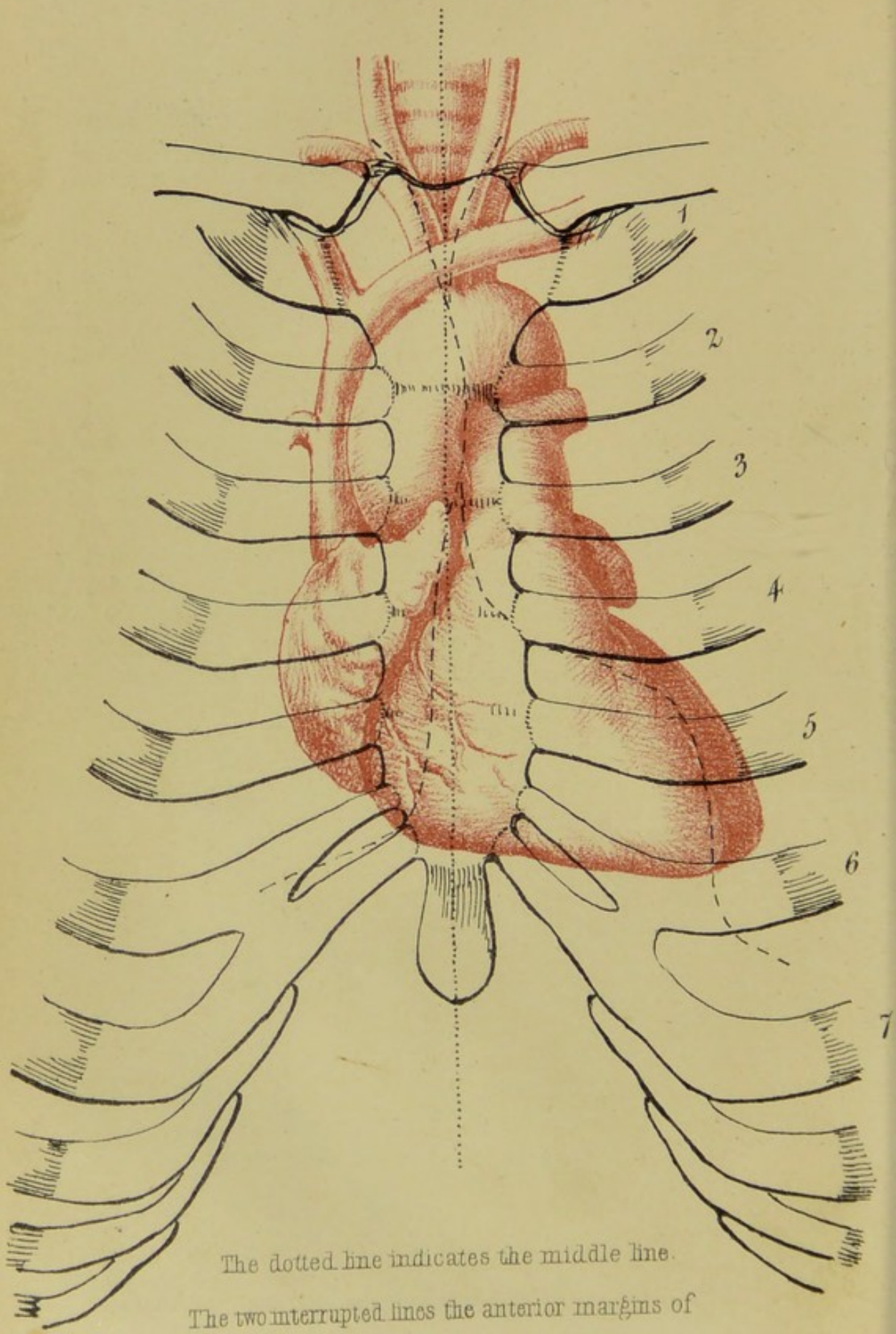
Dr. Allen Thomson's Paper on the Heart.

Sketch illustrative of the Position of the Heart and Large Vessels as seen behind the Sternum & Ribs.



The dotted line indicates the middle line.

The two interrupted lines the anterior margins of the Lungs in a state of full insufflation.—

NOTICE OF M. E. GROUX'S CASE, &c.

THE members of the medical profession in Glasgow have lately been much interested by the view of one of those rare cases of congenital defect of the sternum, which expose partially to observation the motions of the heart, in the person of Mons. E. Groux, a native of Hamburg, who has for some years devoted himself to the exhibition of the peculiarities of his case to the medical public in different countries, and who, by his intelligence and obliging disposition, contributes greatly to the interest excited by the peculiarities of his case. Having had several opportunities of examining M. Groux, and having been requested to give some account of his case in this Journal, I will lay before the reader a short statement of the phenomena which it presents, and of their bearing upon the history of the normal position and action of the central organs of circulation.

M. Groux is twenty-seven years of age, below the average male stature, and of a slim habit of body. He was originally engaged in mercantile business, but did not when so employed enjoy very good health, having suffered repeatedly from pleuritic and other pulmonary attacks. About six years ago he adopted the suggestion of friends, that he should travel to different countries for the purpose of exhibiting himself to the medical profession; and it would appear, that since he made this change in his mode of life, his health has been much improved. Though not robust, yet the muscles are well developed in M. Groux for a person of his stature, and the great pectoral muscles especially, both in the pectoral and clavicular parts, seem to possess an unusual degree of strength, as exhibited by their action on the upper limbs, and in separating the divided parts of the sternum. It is true, that after having been long under the observations and experiments of the many persons who make investigations of his case, M. Groux is subject to some degree of nervous agitation and to local excitement of the organs of circulation; but at other times the congenital defect does not appear to be the cause of inconvenience to him, nor has it ever been so at any period of his life; and all his motions and actions, with the upper as well as the lower limbs, seem to be nearly as free as in other persons. Nor does the fissure produce any great deformity in his person, when exposed. In the state of quiescence of the limbs and respiration, a shallow, somewhat irregular groove, about an inch in breadth at the upper end, or between the clavicles, and narrowing somewhat suddenly to a point at the lower end, in the shape therefore of an elongated V, occupies the three upper-fourths of the sternum, near the middle

line. The integuments with the subjacent fasciæ, apparently without any strong ligamentous bands, passing across from one side of the breast to the other, sink into the groove to a depth of about half an inch; here, however, the skin may be raised nearly to the level of the rest of the breast, when put upon the stretch, by M. Groux widening the fissure, as he is capable of doing to a considerable extent by a forcible action of the great pectoral muscles. It is in this groove, and below the integuments, that various parts of the motions of the heart may be partially observed by touch and sight; and that several other phenomena of interest, such as those connected with respiration, may also be in part examined.

The result of the best observations which have been made in M. Groux's case, does not appear to be inconsistent in any important particular with the previous views of anatomists and physiologists as to the position and action of the heart; nor can it be said that these observations have as yet led to any important discovery of new facts. Nevertheless, all those who have given attention to this case have felt it to be deeply interesting, as enabling them to observe and examine more directly the motions of the heart in the human body. Some phenomena, indeed, have been observed, which seem to lead to a slight modification of the usually received description of the heart's action; and it is not improbable that others may yet be detected which will render our knowledge of this subject more complete.

The case appears to me to be more peculiarly valuable, as furnishing a test of the accuracy of different methods of observation, as applied to the examination of the central organs of circulation; and as affording very strong evidence of the extreme care and caution with which the statements of experiments on the consentaneous and successive occurrence of rapidly succeeding motions must be made, and of the great accuracy and long experience necessary to give value to such observations in the normal state, and still more, to apply them to the explanation of diseased action.

M. Groux carries with him a book, or album, in which the various medical men who have examined him are requested to state their opinions of the nature of the phenomena presented by his case; and certainly this collection of medical opinions possesses very considerable interest: for, besides constituting a remarkable medical autographic curiosity, it is also most instructive in exhibiting a wide diversity of opinions respecting the phenomena of the case and their explanation, and not unfrequently respecting matters considered by many to be so well ascertained as to be beyond the reach of dispute. In this album it will be seen, that the greater number of the observers have prudently contented themselves with a statement of the interest they have felt in the case. Some, as Professors Hammernik of Prague, and Dr. Ernst of Zurich, have described with great care and accuracy all the phenomena of M. Groux's case, and their relation to the generally received

views of anatomists and physiologists. But it must be confessed that some of those who have hazarded the expression of their opinions have fallen into errors, which have only shown that they must have been deficient in the preliminary knowledge and in the powers of accurate observation, which would have enabled them to appreciate correctly the nature of the phenomena passing before them in this case. Before describing these phenomena, therefore, it may be proper for me here to make some preliminary remarks on the generally received views of anatomists and physiologists respecting the normal position and actions of the heart. These remarks may with propriety be confined principally to the anterior parts of the organs in the mediastinum, as bearing most directly upon the peculiarities of the case under consideration.

I.—*Normal position of the organs in the mediastinum, towards the anterior wall of the chest.*—It is not surprising that there should exist some degree of vagueness in the knowledge and opinions of many medical men, and even of some professed anatomists, as to the exact normal position and relations of the heart and the neighbouring parts of the great vessels and lungs, when we consider the absence of symmetry in the form and position of these organs, the peculiar form and directions of the curves of the great arterial vessels, which scarcely admits of precise verbal description, or of accurate pictorial representation, and above all, the extreme liability of all these parts to changes of form and position from their own structure, the mode of their attachment, and the constant variations to which the walls of the containing cavity are subject. The peculiar yielding nature of the mediastinal tissue, the varying size and form of the anterior parts of the lungs in their different degrees of inflation, the great differences in the height of the diaphragm in inspiration and expiration, and, according to the state of the abdominal viscera, besides other circumstances affecting more immediately the shape and position of the heart itself, all tend, in the common modes of examining the body, to create almost insurmountable difficulties in determining with absolute precision the anatomical relations of the organs under consideration.

A glance at the writings of the earlier anatomical and physiological authors who have treated of this subject, also shows the greater difficulties with which they had to contend in consequence of the less frequent and favourable opportunities of making examinations in the human body, and affords an interesting illustration of the vast amount of labour required before preconceived and erroneous views on such a subject come at last to be abandoned. It is worthy of note, that among the ancients, Aristotle, Pliny, and some others, were to a certain extent aware of the difference between the position of the heart in man and animals; and on the revival of anatomy in the sixteenth century, Vesalius and others had become still more fully cognisant of the peculiarity of the situation and relations of the human heart. It is in the works of

Eustachius, however, more particularly, that the most correct representation of these relations, and of the form and position of the human heart, appears first to have been given, as will be seen by reference to the original editions of his "Tabulæ Anatomicæ," or the more recent edition by Albinus.* Nevertheless, long after the time of Vesalius and Eustachius, many anatomists seem to have clung to the older views, founded on the examination of brutes; and it was not till after the middle of the last century, when anatomical descriptions and nomenclature had undergone great general improvement, that the peculiarities of the anatomy of the human heart seem to have been fully acknowledged and more accurately described. This was mainly the result of the investigations of Pechlin, and the classical descriptions of Winslow, as may be seen from the luminous account which has been given of the subject in Haller's "Elementa Physiologiæ," tom. 1, p. 299, ann. 1757, and in Senac's "Traité du Cœur," tom. 1, p. 130, ann. 1783. In our own day, while the main facts of the matter are admitted by all those who have any acquaintance with anatomy, and systematic works give, on the whole, a correct description of them, it is yet often felt that there is something wanting to render these descriptions easily intelligible, and to lead those not fully versed in anatomical knowledge to comprehend more readily the nature of the structural peculiarities; and accordingly, with the view of adding precision to the details of the subject, various expedients have of late been resorted to, among which may be mentioned, that of inserting long needles in certain directions into various parts of the organs examined, so as to mark their true relation to the walls of the cavities after they have been opened.† It is not to be doubted, that in some instances useful and precise information may be obtained by this method; but, on the whole, I am inclined to prefer the plan of examining the form and position of the organs by means of a series of partial dissections in which small portions of the walls of the chest are removed at a time, and the viscera are observed as nearly as possible in their normal relations. With an examination conducted in this manner, the results of percussion and auscultation are, of course, to be carefully compared. The very interesting papers on the normal and abnormal situation and structure of the viscera of the chest, published by Dr. Sibson in the "Transactions of the Provincial Medical and Surgical Association,"‡ contain an account of an extensive series of examinations bearing upon this subject; and Dr. Sibson's views have since received greater extension and

* Ann. 1744. Vid., tab. xv.

† An account of the result of such experiments is given in a paper by Dr. Jos. Meyer, in Virchow's Archiv. for 1852, which I have not had an opportunity of consulting. M. Aran appears to have followed the same method. See his treatise on "Diseases of the Heart," translated, Philadelphia, 1843.

‡ Vol. 12, year 1842.

illustration in his large work on medical anatomy, now in course of publication.

I have for my own satisfaction at various times, and more recently with the assistance of Dr. Peter Young, my demonstrator of anatomy, made a number of such dissections; and I will here give a short account of the results, in so far as they bear upon the illustration of M. Groux's case. For the determination of the organs situated near the middle line or plane of the chest, the simplest plan is to remove carefully the whole of the sternum, with the exception of the upper third of the manubrium, the whole of the ensiform part, and the attachment of the seventh costal cartilages. The costal pleura is to be kept uninjured, and the lungs may be inflated more or less from an aperture in the trachea, so as to observe their extent in front in their various conditions. The fourth and fifth costal cartilages of the left side may afterwards be removed to the extent of between two or three inches from the sternum, so as fully to expose the precordial region. The viscera of the abdomen ought to be well supported by bandaging, and the examination of the body may be then made either in the horizontal or sitting posture.

For the determination of the place of attachment of the mediastinal tissue in front, it is best simply to leave the sternum entire, to remove the costal cartilages and part of the ribs on each side, and to open the cavities of the pleura; and thus, when the lungs collapse, the mediastinal tissue is drawn backwards from the line of its attachment to the posterior surface of the sternum, and its relation to the middle line may then be observed with the greatest ease and precision. The accompanying sketch is intended to give a general view of the result of such examinations, in so far, at least, as can be truly represented from before.

By proceeding in the second of the methods above indicated, we have found considerable variety in different subjects as to the place of attachment of the tissue of the anterior mediastinum to the wall of the chest. In the great majority of instances, the line of this attachment is not far from the middle of the sternum, tending somewhat obliquely to the left side as it descends. In most cases it is slightly to the left of the middle line throughout its whole extent. In a few, it is perceptibly to the right above; but in all, it is to the left inferiorly. In one instance we have found the whole line of attachment so much to the left as to be close behind the left border of the sternum superiorly, and some distance beyond it inferiorly. It is well known, that when the lungs are fully inflated, the border of the upper lobe of the right lung either meets that of the left in the middle behind the upper part of the sternum, or passing a little to the left of the middle line, overlaps the edge of the left lung; so that the tissue of the mediastinum must be stretched obliquely over the reflected pleuræ. The anterior border of the right lung, however, is not usually straight, but

projects over the middle line to the left, chiefly at the level of the second intercostal space; it then descends somewhat obliquely to the right, close to the middle line, till it reaches the lower part of the precordial region. The anterior border of the left lung, after descending on the left of the middle line to the third intercostal space, diverges suddenly in the same direction, so as to leave the pericardium exposed in front for a space of about three inches or more in breadth transversely, and about two or two and a half inches in the vertical direction, in the well-known precordial region corresponding to the cartilages of the fourth and fifth ribs, and the intervening intercostal space.

When again we follow the first of the two methods of examination previously indicated, by removing the sternum, &c., and dissect carefully between the mediastinal pleuræ, we readily recognize the undisturbed position of the various organs which occupy the immediate vicinity of the middle plane, viz., in succession from the upper part of the sternum downwards; 1st, the left innominata or brachio-cephalic vein passing in front of the innominata artery; 2nd, the ascending part of the arch of the aorta, as far as the origin of the artery now named, covered by pericardium, and in its upper part, generally also by the thymus gland, fat, &c.; 3rd, the right auricular appendix; and, 4th, the right ventricle, extending as far down as the lower end of the body of the sternum.

1. Of these parts the innominata vein crosses obliquely from left to right, and downwards, its upper border being on a level with the summit of the sternum at the left side, but half an inch below it on the right side. It lies very close in front of the first part of the innominata artery, and its lower border is parallel to, and rests upon, the summit of the arch of the aorta, as it passes into the ascending part. The middle of the innominata artery, at its origin from the arch, is rather to the left of the middle line.

2. The summit of the arch of the aorta is on a level, in general, with the middle of the manubrium, or nearly an inch below the interclavicular notch of the sternum. This, and the upper part of the ascending portion of the arch, are at some depth behind the sternum, and are separated from it by the overlying thymus, lymphatic glands, fatty and binding tissue, and by more or less of the lungs, according to the degree of their inflation. The middle point of the aorta, where it springs from the left ventricle, is as nearly as possible in a line behind the left border of the sternum, at the level of the third intercostal space. The right border, therefore, or convexity of the ascending part of the arch, may be described as commencing at this level, very nearly behind the middle line, and extending to the right forwards and upwards. The most projecting part of the curve passes to the right of the sternum, more than a quarter of an inch, at the level of the lower part of the second right costal cartilage, and then turns backwards

and upwards into the middle part of the arch. It is the middle part of the ascending portion of the arch, or what is often called the great sinus of the aorta, which tends to project most forward between the lungs, and would therefore be most liable to be felt pulsating if the sternum were removed at this place.

It does not fall within my present purpose to describe the posterior part of the arch; but in passing, I may be allowed to make a remark on a peculiarity of its form, which, though well enough known to most anatomists, is not generally clearly described. I allude to the lateral curve formed by the middle part of the arch, which presents a hollow to the right side, in which the trachea and œsophagus are partly situated. It is this curve, towards the right, together with the obliquity of direction of the whole, as it passes backwards in the chest, which causes the arch to occupy so small a breadth of space transversely, that the lines produced forward from the most projecting parts of the first and last parts of the arch, are not more than $2\frac{1}{4}$ or $2\frac{1}{2}$ inches apart in a transverse direction.

The concavity of the ascending part of the aortic arch beginning in the third intercostal space to the left of the sternum, in curving upwards and to the right, does not reach the middle plane, and then turning with a sudden bend to the left, and backwards over the right pulmonary artery and left bronchus, attains the level of the junction of the manubrium with the body of the sternum. The trunk of the pulmonary artery is situated entirely to the left of the middle line, and never reaches it at any point. Its commencement is a little higher than that of the aorta, or nearly on a level with the lower border of the third left costal cartilage. The pulmonary semilunar valves are placed, in fact, immediately behind this cartilage, and partly under cover of the left border of the sternum. The left border or convexity of the pulmonary artery lies about three quarters of an inch to the left of the sternum, and the left pulmonary artery, as it passes towards the lung, lies deeply on a level with the second costal cartilage. The pulmonary artery is covered in front by the left lung.

3. Third in succession from above, downwards, on the same level with, and to the right of the pulmonary semilunar valves (as has been described by Dr. Sibson), and covering exactly the middle line, is the apex of the right auricular appendix, extending about a quarter of an inch or more to the left over the middle line, in a pointed form, and widening to the right into the larger part of the auricle. The commencement of the aorta is covered by this auricular appendix on the right, and by the first part of the pulmonary artery on the left; but when the pericardium is opened, the aorta may be touched in the interval between these parts. To the right of the sternum at the same level, that is, behind the third right costal cartilage, and on a deeper plane, is placed the entrance of the vena cava superior into the auricle. A line passed

directly backwards, touching the right border of this vein, would be about three quarters of an inch to the right of the sternum; and thus it will be seen that the vena cava superior, the ascending aorta, and the pulmonary artery, together, form a mass which fills a space nearly of equal extent on either side of the mesial plane. To the left of the pulmonary artery, but on a deeper plane, is situated the left auricular appendix. Immediately below the right auricular appendix, and crossing the middle line obliquely from left to right downwards, is the fissure between the right auricle and ventricle, extending downwards to the junction of the sixth right costal cartilage with the sternum. This is the situation most common in males, but in females it frequently happens, apparently in consequence of the deformity of the chest, caused by dress, that the lower costal cartilages are driven inwards on the lower end of the sternum, and the xiphoid cartilage and lower end of the sternum appear higher than in males, in proportion to the lower part of the heart and pericardium.

4. Lastly, the interval between the fourth cartilage and the lower end of the sternum, is occupied by the most projecting part of the right ventricle, which lies within the pericardium, close behind the sternum at this place. The right auricle, lying to the right of this and posteriorly, extends to an inch or more beyond the right border of the sternum, but on a deeper plane, and is covered by the anterior part of the right lung. The base of the right ventricle extends slightly beyond the right border of the sternum inferiorly, when it is also overlapped by the right lung. The cone of the ventricle passing to the pulmonary artery, lies behind the left half of the lower third of the sternum, and the fourth left intercostal space, and fourth left costal cartilage. The extreme left border of the right ventricle extends nearly three inches to the left of the middle line, to the interventricular notch and groove. The line of the lower anterior border of the heart is nearly parallel to the oblique plane in which its inferior surface lies on the central tendon of the diaphragm. This plane is very nearly horizontal, passing across the place of junction of the sternum and ensiform cartilage, to the upper border of the sixth left costal cartilage. In the sitting posture, the apex of the heart is situated at the left extremity of the anterior border, about three and a half inches from the middle line. In the detached heart, anatomists are still in the habit of describing the lower flat surface of the heart as the posterior surface, and the anterior sharp border as the right border. In viewing the ventricular part of the heart from before, the left ventricle is placed so much to the left of, and behind the right, that not more than an inch in breadth of the left ventricle appears to the left of the interventricular groove.

II.—*Anatomy of M. Groux's Case.* The foregoing anatomical data will enable us to determine with precision the relation between certain parts of the organs of circulation and respiration,

and the anterior walls of the chest in M. Groux's case. The congenital fissure which divides the sternum extends nearly vertically downwards through the manubrium and body of the bone, till it reaches the ensiform cartilage, where it ceases, or is interrupted by the union across the middle line of the cartilages of the seventh ribs. The fissure appears to be placed not exactly in the middle of the sternum, but rather to the right of the middle line, so that the left segment of that bone is rather broader than the right one. At the lower part of the neck the division of the manubrium causes the separation of the folds of skin over the sternal tendons of the sterno-mastoid muscles to some extent. There is a peculiarity also in the attachment of the sterno-hyoid muscles at their lower part, which is not in the same manner accounted for by the fissure. In the state of rest, these muscles are not prominent; but when thrown into contraction, it is perceived that the right, in place of joining the right segment of the sternum, or passing behind the right sterno-clavicular articulation, as might have been expected, descends obliquely along with the left muscle, to pass behind the left sterno-clavicular articulation. By some who have described M. Groux's case, the raised fold of skin caused by the action of these muscles, has been stated to contain also the right sterno-thyroid muscle; but I find this not to be the case, as the right sterno-thyroid muscles may both be recognized in a deeper region when in action, by the folds of skin raised at their inner edges, which are symmetrically placed, and are separated from each other in the same manner as the sterno-mastoid muscles. In the state of rest of the parts, the fissure, though really extending through the whole sternum, appears to proceed no farther than the cartilages of the fifth ribs, as from that point downwards the edges of the sternum, covered by the integuments, lie close together. When the fissure is widened, however, by a strong action of the great pectoral muscles, it may be clearly seen and felt that it extends as far as the xiphoid cartilage.

There does not appear to be any reason to think, that beyond the fissure itself, and the separation of the muscles, &c., above referred to, there is anything very abnormal in the structure or situation of the organs in or near the mediastinum; and we may therefore conclude, founding upon what has been observed in regard to the normal condition, that the following parts must lie behind the integuments, at a somewhat variable depth, and from above, downwards, in M. Groux's fissure, viz.:—the left vena innominata, the middle part of the ascending aorta, the apex of the right auricular appendix, and the cone or projecting part of the right ventricle. Of these parts the auricular appendix corresponds exactly, in situation, with the small pulsating tumour, which is on a level with the third costal cartilage. If there is any difference between the normal situation of parts, and that in M. Groux's case, it may consist in a slight apparent displace-

ment of the whole to the left, in consequence of the fissure not being placed precisely in the middle line of the body, or rather of the right side being somewhat smaller than the left. I have, like M. Hamernik, found that the measurement of M. Groux's chest, from the dorsal spines, (which present no appreciable lateral curvature,) round the chest over the nipple, gave a length on the left side about three-fourths of an inch greater than on the right. If thus the fissure is brought nearer to the right side, the viscera presenting in the fissure would have the appearance of being displaced to the left. At the same time, it is also proper to notice that the upper and anterior portion of the right lung appears to have undergone some preternatural enlargement, which has extended to its pleural cavity, so that when compressed, as by coughing, or any sudden action of the expiratory muscles, this portion of the lung makes a very considerable tumor or convexity of the integuments occupying the upper half of the fissure, and extending for several inches above the sternum into the neck.* It is difficult to comprehend how this hernia has arisen. From the extreme degree of resonance on percussion in the dilated condition of this portion of lung, it appears as if it were emphysematous. But I was informed by M. Groux that it had not undergone any increase within his recollection; and had it been emphysematous, with the treatment to which it is subjected in his exhibitions, this would very probably have been the case. It is not improbable, as M. Hamernik has suggested, that the mediastinal tissue may have its principal attachment, in M. Groux's case, to the left segment of the sternum, and that the hernial enlargement of the right lung may have been favoured by this disposition. I have shown that in the majority of cases, the mediastinal tissue is normally attached somewhat to the left of the middle line of the sternum; and we may suppose that such a disposition in M. Groux's case might have led to its exclusive attachment to the left, and its disengagement from the right segment of the sternum.

The slight displacement of parts to the left, above referred to, has the effect, I conceive, in M. Groux's case, of bringing a greater portion of the right auricle into the middle of the fissure than might be found in the dissection of the parts in a normal state; and this may in some degree explain the difference of opinion which seems to exist among those who have examined M. Groux, upon a point in regard to which we might have expected to have found them more agreed. It is fair also to remark, that very probably some differences in the position of the parts in question may exist without abnormity in different individuals.

* Many years ago I saw an example of a remarkable cervical hernia of the lungs in a child in the last stage of hooping-cough. This occurred on both sides of the neck, in the region of the scalene muscles, where two tumours, each about the size of a small orange, were alternately dilated and contracted with every effort of expiration and inspiration. In M. Groux, the hernia only becomes visible in efforts of expiration, between the sterno-mastoid muscles.

Although I am of opinion that the pulsating tumor corresponds to the auricular appendix in the state of quiet, yet it is far otherwise when M. Groux, by suspending the respiration for a time, causes the tumor to enlarge and spread itself in the groove. The distension of the tumor, with blood arrested on the right side of the heart, then causes its extension downwards into the region occupied by the right ventricle; and I have remarked that when this distension is to a great degree, a groove may be perceived below the integuments crossing the tumor below the place occupied by the auricular appendix, and passing obliquely downwards from left to right, thus dividing it into a smaller upper and a larger lower part, and corresponding in situation and direction to the transverse groove of the heart, which separates the right auricle and ventricle.

The congenital malformations of the chest, which expose more or less the actions of the heart, are not very uncommon. The very various forms in which they have been observed to occur, may be divided into three sets or gradations as follows, viz.—1st, Very slight deficiency in the ossification of the sternum; 2nd, Great or entire fissure or division of the bone; and, 3rd, Absence of the sternum, combined with want of other parts of the thoracic and abdominal parietes, or with still greater malformations.

1. In slight affections of this kind, a deficiency in the ossification of the sternum presents itself most frequently in the bifid condition of the xiphoid piece, or of a perforation in it, or in the lower part of the body of the sternum—an appearance sufficiently familiar to all anatomists. Such perforations more rarely affect the manubrium or upper part of the body of the sternum, a circumstance which may be connected with the different mode of ossification in the upper and lower parts; the ossific centres being generally single and median in the manubrium and upper part, but double and lateral in the lower part of the body.

2. The extreme degrees of this deficiency of the thoracic wall are attended with an entire absence of the sternum, and more or less of the ribs in its vicinity, and are not unfrequently accompanied by absence or cleft of the abdominal wall, and great exposure of the viscera, as well as other deformities.

3. M. Groux's case belongs to an intermediate degree, in which the sternum is present, but cleft in its whole length. But among these also very various gradations of the defect appear to have been observed. In some, as in M. Groux, each half sternum appears to be fully ossified, and nearly naturally formed. Professor Bennett of Edinburgh has described in M. Groux's album, an interesting preparation of a sternum precisely in a similar condition, which he placed some years ago in the museum of the university of Edinburgh, and which was obtained from the body of a woman who died in the Royal Infirmary of that city, but without the deformity having been perceived during life, so as to

lead to the observation of the condition of the organs within the chest. In his work on Auscultation,* Skoda has described a case apparently similar to that of M. Groux:—

"On the 8th of March, 1846," says he, "I examined a child, a few days old, in whom the sternum was wanting, and whose thorax, in consequence, presented in front a cleft, narrow above and broad below, and closed in merely by integuments. At each inspiration the skin was forced backwards towards the vertebræ, and the anterior ends of the ribs thereby bent somewhat inwards; during expiration the skin pressed outwards in the form of a bladder. It was readily ascertained by palpation that the heart lay in a vertical direction, . . . and at each systole the impulse of the heart could be felt above the insertion of the diaphragm, and at each diastole, on a level with the second rib, provided the finger was pressed deeply enough towards the vertebræ at that point."

In the description of figure 1 of table xiv. of Ammon's work, he has given from Wittstock an account of a case of congenital fissure of the sternum, published by that author in 1838, at Rostock:—

"The sternum was entirely wanting, with the exception of the ensiform cartilage, and that even in an imperfect condition; the anterior ends of the ribs were united on each side only by ligamentous substance, and a deep groove existed between those of opposite sides. The pulsation of the heart was clearly seen through the integuments in this groove, which also sunk or protruded with the motions of inspiration and expiration."

In one or two other recorded examples of median fissure of the chest, the sternum has been found almost entirely absent, or the anterior ends of the ribs have been united only by a slight vertical ligament on each side of the fissure.

Sternal fissures are to be looked upon like other malformations of a similar kind, as of the general nature of arrests of development leading to want of union along the middle line. And, accordingly, we find these fissures running variously into one another from different parts of the trunk, as from above downwards towards the umbilicus, and combined, it may be, with umbilical hernia; or extending more or less from below upwards, and consisting below in the absence of union at the pubic symphysis, running up more or less towards the umbilicus, and then frequently combined with ectroversion of the urinary bladder, and in other cases even reaching up to the thorax.† In some malformations of this kind, and even as it would appear without any great deficiency or opening of the thoracic wall, the heart has been completely displaced from the thorax, and has been seen hanging free in front of the chest. Such appears to have been the condition in a case described by M. Breschet in his interesting memoir, "l'Ectopie de l'Appareil de la Circulation," published in his "Répertoire

* I quote from the translation of the third edition, by Dr. Markham, London, 1853. See note at p. 155.

† See the work of Ammon, "Die angeborenen Chirurgischen Krankheiten," fol., Berlin, 1839–42, tab. i. iv. and xiv., for views of several such cases.

Générale d'Anatomie et de Physiologie Pathologique," tom. ii., p. 1. And also in the case of a child observed and described by M. Cruveilhier in 1841,* and in which he was enabled to make a series of interesting observations on the motions of the heart. I regret I have not the opportunity of referring to M. Cruveilheir's paper. The case is also referred to by Skoda, in his work on Auscultation, p. 181, and the following description is given :—

"The heart of the child—which was in other respects well developed and full of life—lay outside the thorax, passing through a round opening in the upper part of the sternum. It was uncovered by pericardium, and completely bare; its colour pale, and surface dry. Its position changed when the child's posture was altered. When the child was placed vertically, the heart sunk considerably, and its great vessels became visible. The axis of the heart was vertical."

Another case of a similar nature was described by M. Monod, in the "Bulletin de l'Académie de Médecine," for February, 1843 † A third case of an analogous nature with prolapsus of the heart was described by Chaussier, in the "Bulletin de la Faculté de Médecine." And I find in Portal's "Anatomie Médicale," and in various other works, a reference to an interesting and well-described observation of a case of displacement of the heart, by a Spanish physician named Martin Martinez, which I presume to have been of a congenital nature, and in which he was able to examine with ease the movements of the heart.‡ It would appear, however, that in all those cases of sternal deficiency or fissure in which the heart has been displaced from the cavity of the chest, the pericardium has also been absent, and the heart has been completely exposed, a condition incompatible with the maintenance of life; and accordingly, in most of these instances, death has occurred immediately on birth, or a very short time afterwards. It seems probable, therefore, that besides the mere deficiency in the median sternal union, more serious pathological causes have concurred to produce the defective condition. But in M. Groux's case, and in several others of a like kind, such as that of a girl described by Ammon, and another case related by Cullerier, in which the fissure existed only at the upper part,§ the deficiency of the bony walls producing the fissure has not led to anything unnatural in the form or position of the thoracic organs; and as the soft integuments pass across the deficiency in the sternum, the heart is naturally situated in the pericardium, and its motions may be more or less clearly perceived according to the extent of the deficiency of the bony parietes. In such cases also, as we have seen in M. Groux, the defect does not seem necessarily to lead

* "Gazette Médicale de Paris" for 1841, No. xxxii.
† See Edinburgh Medical and Surgical Journal for July, 1843.
‡ "Observatio de Corde," Matriti, 1723.
§ See "Jour. Gén. de Médecine," tom. lxxiv.

to any great inconvenience or to dangerous symptoms as connected with the organs of circulation and respiration.*

Winslow, in the "Memoires de l'Academie," 1740, and Sandifort, in his "Museum Anatomicum," have described instances of congenital fissure of the sternum in birds. And it was very remarkable to find in a case of complete fissure through the whole length of the bone in a pigeon, as described by Winslow, that the defect did not interfere with the action of the great pectoral muscles so as to prevent its flying. I have previously called attention to the strength and powerful action of the pectoral muscles in M. Groux.

Our attention is naturally drawn at the same time to those cases in which, from accidental injury or disease, the heart has been exposed, and its action observed. Harvey has related in his work on Generation, the case of a young nobleman, afterwards to be referred to, in whom, from an abscess affecting the thoracic parietes, the apex of the heart and part of the ventricles could be felt and seen. Galen was witness of a case of this nature in a man from whom he removed a portion of the sternum which was in a state of disease, and it is remarkable that this man seems to have recovered, although the heart had been deprived of its pericardium by ulceration.

Portal, on whose authority, as given in his interesting work on "Medical Anatomy," tom. i., p. 329, I make the foregoing statement, was himself the observer of the case of a man at the Bicètre hospital in 1767, in whom the sternum and cartilages of the last three true ribs had been lost by carious disease, and in whom the movements of the heart could be perceived through the exposed pericardium. He refers to the "memoire de La Martinierè, sur le trépan du sternum," in the "Mem. de l'Acad. de Chirurgie," tom. iv., p. 544, for a description of other cases. And, doubtless, the records of surgery may present other instances of an analogous kind.

III.—*Motions and Action of the Heart in a natural state.* After the very clear descriptions of the motions and action of the heart which have been given by all the great masters of physiology,

* For farther references to cases of sternal fissure and malformations of a similar kind, I may refer to the systematic works of Otto and Meckel on "Pathological Anatomy," and to Isidore Geoffroy St. Hilaire's and Vrolik's works on "Congenital Malformations," together with that of Ammon already cited. The dissertations of Wiedemann, "Uber das fehlende Brustbein," Brunswick, 1794; and "Fleischmann, De Vitiis Congenitis circa Thoracem et Abdomen," treat more specifically of this subject. According to Portal, Senac has described in his work on the heart a remarkable example of fissure of the sternum occurring not merely in one individual, but in a whole family, thus indicating the tendency of this, like other malformations, to hereditary transmission: but I have not had time to find the passage in Senac's work in which these cases are described. M. Groux was not aware of any members of his family having been similarly affected with himself.

from the time of Harvey down to the present day, the general agreement of their views, and the reiterated confirmation which they have received from the observations of every physiologist who has examined these motions for himself with sufficient care and accuracy, it appears surprising that some persons should still look upon the order of succession of the different parts of the heart's action as a matter of doubt, and that from time to time there should be brought forward views upon this subject altogether inconsistent with some of the best ascertained facts in the whole range of physiology. We shall see that M. Groux's case has furnished the occasion for the multiplication of these erroneous statements.

I should not have ventured to make any remarks here upon a subject that may appear to many to be of a very elementary nature, had I not been convinced by the perusal of some recent writings, that there is prevalent too little precision in the knowledge of it, and too great a disposition to set aside, without due consideration, the experimental evidence upon which the older and more general views of the heart's action have been founded. It must be admitted also, and it has been felt by all those who have observed for themselves on this subject, that the motions of the exposed heart of a warm-blooded animal are not followed by the inexperienced eye without great difficulty; so that the mistakes often made by a novice in these experiments are perhaps excusable. But the most experienced even is sometimes apt to be misled; and it is only by very frequent and careful observation of the heart in a great variety of conditions—when it is in full vigour —when it has become languid from approaching dissolution—and when its action is modified by various reagents; by observations directed to the fœtal as well as to the adult heart, and to the hearts of the cold-blooded animals; and by the comparison of the results obtained in these various modes of investigation,—that we come to follow with accuracy the rhythm or order of succession of the motions in the several parts of the heart, and acquire the experience necessary to enable us to avoid the many sources of fallacy to which our observations are liable. I think, therefore, that before proceeding to state the result of observation and experiments, with reference to the motions and action of the heart, it may not be out of place to show the reader with what caution, and through what difficulties, the earlier experimenters arrived at the conclusions which form the foundation of our present knowledge of this subject.

The motions of the heart are thus described by Harvey, in his "Anatomical Disquisition of the Motions of the Blood," &c. I quote from the Sydenham Society translation, p. 31:—

"First of all the auricle contracts, and in the course of its contraction throws the blood . . . into the ventricle, which being filled, the heart raises itself

straightway, makes all its fibres tense, contracts the ventricles, and performs a beat, by which beat it immediately sends the blood supplied to it by the auricle into the arteries, &c. . . . These two motions, one of the ventricles, another of the auricles, take place consecutively, but in such a manner that there is a kind of harmony or rhythm preserved between them, the two concurring in such wise that but one motion is apparent, especially in the warm-blooded animals, in which the movements in question are rapid. . . . If any one bearing these things in mind will carefully watch the motions of the heart in the body of a living animal, he will perceive not only all the particulars I have mentioned, viz., the heart becoming erect, and making one continuous motion with its auricles—but farther, a certain obscure undulation and lateral inclination in the direction of the axis of the right ventricle, (the organ) twisting itself slightly in performing its work."

Haller has described the action of the heart from his own observations in a great variety of animals.* He says ("Elementa Physiologiæ," tom. i., p. 417)—

"Post auricularum constrictionem celerrime in calido et sano animale, aliquanto lentius in frigido et languente, et nonnunquam satis magno etiam in calidis tempusculo interposito, sequitur ventriculorum contractio; sequitur, inquam, cum in plurimis experimentis ita viderim in fele, cane, glire, facillime vero in pullo incubato; et cum plerique prioris ævi prosectores, in vivorum animalium incisionibus innutriti, motum ventriculorum auricularum constrictionem sequi, testes se offerant, alternasque auricularum et ventriculorum contractiones suo experimento confirmaverint."

Again at p. 418, after stating the view of Lancisi, that the contraction of the auricle, though beginning before that of the ventricle, runs into it by two-thirds of the whole time occupied by the auricular contraction, Haller states the result of his own observations, showing that the ventricular usually follows in quick succession the auricular systole:—

"Frequentissime certe in piscibus, ranis, lacertis, corvis, ululis, pullis incubatis, muribus, gliribus, suibus, cuniculis, hædis, ovibus, canibus, felibus, erinaceis, et absque omni dubio vidi, auriculas cordis prius repleri quam ventriculi repleantur, et prius pariter contractas inaniri, quam iidem ventriculi evacuantur, quo tempore thalami in diastolen se remiserunt, et eo ipso tempore rubro sanguine ab auriculis impulso distenduntur. Paulo post auriculæ quiescunt, et cordis ventriculi constrictionem moliuntur, suumque sanguinem expellunt, ut manifesto satis præcessionem auricularum cordisque proxime sequentem constrictionem, distinguas."

Senac holds precisely similar views. At p. 32 of the second volume of his work, "De la structure du Cœur," 1783, he says—

"Si on en appelle au témoignage des yeux, on verra certainement que les contractions des veines caves et des oreillettes, des oreillettes et des ventricules, des ventricules et des grandes arterès, se succédent exactement; on voit surtout cette succession, quand le cœur commence à languir."

Referring to the view of Lancisi, Senac observes, p. 33, that in a heart acting naturally, the eye fails to detect the succession of the auricular and ventricular contractions, so rapidly are they effected, and so closely associated; but, nevertheless, the succession

* "Deux Mémoires sur le Mouvement du Sang," &c., Lausanne, 1756.

is to be perceived in languishing animals; and he conceives the later occurrence of the ventricular systole to be necessary, as the auricle, says he, cannot any longer propel its blood into the ventricle, when once the constriction of the latter has begun. Again at p. 35, he says—

"Ces mouvemens des oreilletes sont les premiers mouvemens du cœur; quand elles se contractent, les ventricules se dilatent et se reserrent ensuite; c'est à dire que les dilatations et les contractions sont successives dans ces organes," &c.

Harvey, Haller, and various other writers, have remarked upon the extreme difficulty of making correct observations on the motions of the heart; and Dr. John Reid has expressed similar opinions in his excellent article, *Heart*, in the "Cyclopædia of Anatomy and Physiology," vol. xi., p. 602.

"It is not so easy a matter," says he, "as may at first be imagined, to ascertain the order of succession in which the different cavities of the heart contract and dilate, and the different circumstances which attend these movements, even by experiments on living animals, more particularly the warm-blooded animals; for if the heart when exposed is acting vigorously and rapidly, every one who has examined for himself must have felt the exceeding difficulty of following and analysing these movements by the eye. . . . It is in this way that we can account not only for the discrepant statements of the older observers, but also for the very frequent announcement of new views on this subject which appear in the medical periodicals of our own day."

The description of the action of the heart given by Reid in the same article, and which is founded on those of Harvey, Haller, and Senac, as well as on his own observations, is very correct:—

"When the heart of a living animal is exposed," says he, "and the organ is acting in a natural manner, the auricles are observed to become distended with blood, then to contract rapidly and simultaneously, and propel part of it into the ventricles: this is accompanied by a corresponding enlargement of the ventricles, which is immediately followed by their simultaneous contraction, and the propulsion of their blood along the large arteries; then follows a pause, during which the auricles become distended by the blood flowing along the veins, &c.

"When the heart is acting vigorously, the contraction of the ventricles succeeds immediately upon that of the auricles, so that they sometimes appear continuous; or, in other words, the sudden distension of the ventricles by the blood propelled into them during the systole of the auricles, is rapidly followed by the contraction of the ventricles. . . . When the action of the heart is a little less active, an apparent interval is observable between the completion of the contraction of the auricles and the commencement of the contraction of the ventricles. . . . The ventricles during their systole are diminished in all their dimensions; the apex is drawn upwards to the base, and tilted forwards so as to strike the parietes of the thorax between the cartilages of the fifth and sixth ribs."

In the work of the learned and accurate Johannes Muller on Physiology (translated by Baly, vol. i., p. 182), a precisely similar view of the motions of the heart is given, and the same distinction is pointed out between the actions of the heart in cold and warm-blooded animals, and between the heart of the latter in a vigorous and languid condition; while it is shown, at the same

time, that there is nothing essentially different in the rhythm, or order and manner of recurrence, of the several motions. But I need not refer to a greater number of works to show the general agreement of the first authors on this subject.*

It is foreign to my present purpose to describe in minute detail the phenomena of the heart's action. For this I may refer to the works already quoted, and others of a similar kind. The subject has been more particularly discussed in a masterly manner by Dr. Kurschner in the article, "Herzthatigkeit," in R. Wagner's "Handbuch der Physiologie." I will confine myself here to a very short statement of the facts which bear most directly on the illustration of M. Groux's case.

If the chest of a dog or rabbit, or any other suitable animal, which has been rendered insensible by dividing the medulla oblongata, be opened, and artificial insufflation of the lungs be properly maintained, we may with great convenience observe in it the various phenomena of the heart's action for a period of several hours. It may then be perceived that the heart's action consists in a simultaneous contraction of the two auricles, followed by that of the two ventricles; each of these motions being succeeded immediately by the relaxation of the muscular parts, and a short pause or absence of all apparent action then intervening between ventricular relaxation and the recurrence of auricular contraction.

If we watch more particularly the right auricle, as is more easily done than the left, it is apparent that it is gradually filling with blood which flows into it from the veins, during the whole time its walls are in a state of relaxation: it is most fully distended with blood just before its contraction. The sudden vibratory action of the muscular wall, indicating its contraction, begins first near the great veins, extending even a little way along them; it is quickly propagated through the sinus of the auricle towards the ventricle, and the auricular appendix is among the latest parts to contract. The systolic action passes at once from the auricle into the ventricle without appreciable interval, and even seems in some instances, when the motions are vigorous, as if it lasted still a short time after the commencement of the ventricular contraction. The latter action appears to begin at the base of the heart, but is propagated instantaneously to the whole of the ventricular substance, which becomes suddenly harder and more convex, and as soon as the blood escapes from the cavities the ventricles are diminished in all their diameters; and if that part

* In Kirke's "Manual of Physiology," an equally correct view is given of the same subject—(third edition, 1856, p. 83.) In the description given by Dr. Carpenter of the motions of the heart, in the third edition of his treatise on "Human Physiology," he appears to have been too much influenced by the observations related by Cruveilhier in the case of ectopia cordis in an infant, in which it is manifest there must have been several important peculiarities.

of the wall of the thorax has been left entire, the apex is raised and thrown somewhat to the right against it anteriorly. The blood projected from the ventricles is seen to distend the first part of the large arteries, and the auriculo-ventricular valves being closed, are thrown backwards towards the auricular openings.

The relaxation which follows the auricular contraction may, in favourable instances, be seen to occur during the ventricular systole, and even before it when the action of the heart is languid; but at times it is impossible, in the midst of the more violent motions of the ventricle, to detect the precise time of its occurrence. When the ventricular relaxation succeeds the contraction, the heart is seen suddenly to widen and flatten; its anterior part seems to recede from the thoracic wall, and the whole heart feels comparatively soft and yielding to the hand which grasps it.

An attentive observation at the instant of ventricular diastole enables us to perceive a motion like a recoil within the pulmonary arterial trunk, which indicates the sudden closure of the semilunar valves; and the finger placed firmly on this vessel, or the commencement of the aorta, distinguishes readily the movement of dilation by the ventricular systole, and the short succussion of recoil when the elastic reaction of the vessels accompanies the ventricular diastole.

After these actions comes the period of repose, occupying about a fourth or fifth of the whole time of the heart's action; and during this pause no motion is perceptible, excepting that occasioned by the continued flow of blood into the cavities. The auricles do not empty themselves by their contractions, as the ventricles usually do; and both cavities fill with blood during the whole period of their relaxation, the ventricles being also more suddenly and completely filled by the blood thrown into them by the auricular contraction; it is erroneous, therefore, to suppose that the ventricles are chiefly filled by the auricular systole.

The succession of these actions is more distinctly observed when the action of the heart is languid, and still more clearly in a cold-blooded than in a warm-blooded animal; but there is not the slightest ground for the view that the pause ever intervenes in the natural state of the circulation between the contraction of the auricle and the commencement of the ventricular systole. In a frog's heart the succession of the several motions is so distinct that they may be correctly stated thus.—First, the veins; second, the auricles; third, the ventricle; fourth, the bulb of the aorta; and fifth, the pause; and in a warm-blooded animal, when languid, the corresponding statement in the order of succession is, first, veins and auricles; second, ventricles; third, pause; but never in any other order, excepting in the last stage of weakness, when the auricle may sometimes be seen to contract without the ventricular

systole following, or when the auricle may contract twice or oftener for every ventricular systole: or, farther, when the heart is about to cease acting, if we rouse it to contraction by direct stimulation, we may occasionally perceive that the application of the stimulus to the ventricle excites that part to the first contraction, and the auricular systole follows, and the excitement of the auricle calls forth first the contraction of that part. But in all other circumstances, when the contractions of the heart are maintained by artificial respiration, or even in the empty condition, when the stimulus of the external air may be looked upon as the main exciting cause, and the contractions are spontaneously repeated, the uniform order of succession is that before stated, viz. auricular contraction, ventricular contraction, and pause.

The systole of the right and left auricles is exactly simultaneous, as is also that of the two ventricles. It is only in the fœtus, as I have twice observed in the fœtus of the rabbit, that it has occasionally been found that the right auricle contracted a little earlier than the left.

It is now well known, and generally admitted, that the stroke of the apex of the heart against the chest occurs at the first part of the ventricular systole. In the human heart it would appear that, in the quiescent state, the apex lies as low as the sixth rib, and its stroke a little higher on the wall of the chest, or in the fifth intercostal space, is therefore due to the apex being slightly raised or carried upwards during the systole. But it is probably also due in part to a slight rotation of the ventricles on the longitudinal axis which accompanies the contraction. The apex-beat may be said to be felt most strongly in the first part of the systole, at the instant when the walls of the ventricles, and especially the left, are hardest, and are thus capable of giving a forcible impulse, and while their size is not yet diminished to any great extent by the evacuation of blood. So soon as their size is considerably lessened by the escape of the blood into the arteries, the force of the impulse is diminished; and the moment the ventricles pass into relaxation, they become soft and flattened down, and communicate to the hand the feeling as if the apex receded from the wall of the chest; a sensation which is somewhat deceptive, seeing that the heart is still in close relation with the thoracic parietes. But there is no good ground for believing that the ventricular diastole is attended with more force than belongs to the elasticity of the muscular substance which restores its shape after it has been altered by the systolic action, and to the very slight force which brings some blood from the veins, not merely into the auricles, but also into the ventricles of the heart during the diastole and pause. The apex-beat is therefore, as it were, the circumscribed beat of the apex thrown forward in its hardened condition; the relaxed and flaccid ventricles are incapable of communicating any similar impulse of themselves;

and the passage of blood into them is equally incapable of producing a forcible impulse.

From what has now been said it will be seen, that the contraction of the appendix-part of the right auricle comes nearest to that of the ventricles; and that as the apex-beat coincides with the beginning chiefly of the ventricular systole, any observations on the order of succession of these three phenomena, within so short a space as about half a second, must be attended with considerable difficulty. It seems to me not improbable also, that in some instances, as is supposed by Schiff* to be always normally the case, the contraction of the auricle may really be prolonged into the time of the ventricular systole; so that the auricular diastole does not in these cases occur till towards the end of the ventricular systole. This does not appear to be inconsistent with the due closure of the auriculo-ventricular valves and the expulsive action of the ventricles; but from what I have observed in animals, and from the statements of Haller and others, I am inclined to regard the auricular systole as usually occurring in a distinct time before the ventricular, though, as already observed, without any appreciable interval between them.

According to the concurrent testimony of almost all observers, the two sounds which accompany the heart's action fall within the periods of the ventricular contraction and its first relaxation, and not in that of the pause or auricular contraction. The first or dull prolonged sound begins with the ventricular systole and apex beat, and is of equal duration with the whole ventricular contraction, thus lasting nearly half of the time occupied by a revolution of the heart's action. The supposition that it begins in the auricular systole may have arisen from the extreme difficulty of distinguishing the times of phenomena occurring very closely together. We shall afterwards consider how far the auricular contraction may be manifested by a sound, in those cases in which a slight reduplication of the first sound has been heard.

It does not come within the scope of my present purpose to discuss the cause of these sounds. I may refer the reader, for a short and very clear historical view of the opinions of various experimenters on this subject, to Dr. Newbigging's translation of the treatise on Auscultation, by Messrs. Barth and Roger.† I am inclined to regard the first sound as the product of several causes, such as the vibratory movement of forcible contraction in the muscular parietes—the sudden impulse against the auriculo-ventricular valves, and interior of the ventricles, communicated to the blood—and the escape of the blood with force into the first part of the great arteries; and I agree, therefore, nearly with the views expressed on this subject by Drs. Hope and Williams, and by the committee of the Dublin meeting of the British Association.

* Archiv. für Physik. Heilkunde for 1850.

† Edinburgh, 1842

The short and sharper second sound coincides with the first relaxation of the ventricles and the closure of the semilunar valves. It was first suggested by Carswell and Rouanet in 1832, that the sudden closure of these valves by the recoil of blood from the dilated arteries, might be the efficient cause of the second sound, and that opinion was afterwards proved to be correct by the ingenious and conclusive experiments of Hope and Williams in 1839, and since that time no discrepancy of opinion worthy of being recorded has existed in regard to it.

In looking back, however, upon the history of the investigation of this subject, and contemplating the difficulties to be encountered in establishing a sure basis of well-ascertained facts for pathological induction, we cannot but be struck with the rapid and satisfactory progress which the inquiry into the phenomena of the healthy and morbid sounds of the heart, since the time of Lænnec, the founder of auscultation as a means of diagnosis, who actually held the opinion, that while the first sound was due to ventricular systole, the second was owing to auricular contraction, which he thus made to precede, in place of following, the pause in the heart's action. It was not till the late Mr. John Turner, professor of surgery in the university of Edinburgh, pointed out this error, and by reference to the views of Harvey, Haller, and other physiologists, demonstrated that, at all events, the second sound could not be connected with the auricular action* —that a rational foundation was laid for the diagnosis of the morbid conditions of the heart by means of auscultation.

After all this, it seems difficult to understand how any one who had studied the phenomena of the heart's action, could entertain views differing in any important respects from those generally received; and yet there appears still to be a tendency to the error of placing the auricular contraction immediately after the ventricular systole, as manifested in some recent writings.† I think it possible that, in the observation of the motions of the heart of a living animal, the error of supposing the auricular contraction to follow the ventricular one might arise in the following manner:— When the heart is acting hurriedly, and the cavities are not emptied of blood in a normal manner, it will be found, that while it is extremely difficult, as previously remarked, to separate the auricular from the first part of the ventricular contraction, unless we watch the whole contraction of the auricle (right) from behind, or where it begins in the veins—an apparent contracting motion of the auricular appendix, and of part of the auricle, does actually follow the ventricular systole. But farther observation shows that

* See Transactions of the Med. Chirurgical Society of Edinburgh, vol. iii.

† See Dr. Pavy's paper on the Action of the Heart and M. Groux's case, in the Medical Times and Gazette, Nov. 21, 1857. M. Pigeaux, in 1839, had proposed the same view, and M. Beau had adopted a modification of it equally erroneous.

this is not a motion of active contraction, for it may be easily ascertained by feeling, that the muscular substance of the auricle is at the time perfectly flaccid. The motion appears, in fact, to depend upon this circumstance, that when the ventricle passes into its state of diastole, the auriculo-ventricular valves, which had been previously, during the systole, thrown upwards into the auriculo-ventricular orifice, descend somewhat into the cavity of the ventricle, and the walls of the auricle contract themselves to a small extent by the mere force of elasticity. If care be not taken to analyse this phenomenon, and to ascertain the previous occurrence of the true muscular contraction of the auricular walls, which may be only very slight, we may very readily be misled by the great resemblance which this accidental motion of the auricle presents to a muscular contraction following the ventricular systole.

IV. *Phenomena of the Heart's Action, &c., observed in M. Groux's Case.*—From what has previously been stated it will be apparent, that if it be difficult to determine the progress of phenomena passing before us in the fully exposed heart of an animal, still greater care will be necessary to enable us to pronounce a judgment on those which are only partially disclosed to us by such a case as that of M. Groux. Of this we have abundant proof also in the variety of opinions which have been offered by different observers as to the nature and cause of the motions and pulsations observed in the sternal fissure in his case. The great majority of observers have no doubt agreed in referring the pulsating tumor, situated in the middle of the fissure, to the right auricle; but there are others who regard it as the right ventricle; and others, again, such as Bouillaud and Sibson, who look upon it as the ascending aorta. An attentive observation of these movements, and a comparison of them with the results of observations made in the normal state of the organs of circulation, have convinced me that there is nothing in M. Groux's case at variance with the natural action of the heart and vessels; and that it is possible, if not to reconcile those views which are founded in erroneous observation, at least to show some of the principal causes of the frequent discrepancy of opinion which has prevailed.

The various phenomena of the heart's motions may be observed in M. Groux in several different ways; as, for example, by feeling the pulsations or motions with the fingers; in which case considerable care is required to regulate the amount of pressure of the finger on different parts where pulsations are to be felt, in order that we may appreciate with accuracy their relative intensity, their directions, or the times of their occurrence; or secondly, we may follow with the eyes the elevations and depressions of the surface which are caused by the motions; and we may assist this kind of observation, either by adjusting the body with regard to light, so that the elevations may be made to cast long shadows on

the neighbouring part of the surface, or, as M. Groux is accustomed to do, we may adapt to the various parts of the skin projecting feathers or any long light bodies, which may be fixed by their ends, as indicators of the subjacent motions;* and, thirdly, we may with still greater convenience and advantage, for the close comparison of the motions and pulsations of remote parts, employ instruments constructed after the fashion of the sphygmoscope, fitted with flexible tubes; so that, while the funnel parts of the instruments are applied either to adjacent or to remote parts, the glass tubes, in which the rise and fall of coloured fluid indicating motions or pulsations are to be observed, may be placed close together; and the eye is thus enabled to make a comparison of movements, which would otherwise be extremely difficult, or quite impossible.

The following are the principal observations which I had an opportunity of making in these several ways:—

1. The most obvious phenomenon to be noticed in M. Groux's case is the pulsation and motion of a soft oval tumor of the integuments, situated near the middle of the fissure. This tumor, in its ordinary state, is little more than an inch and a quarter in length from above downwards, and narrower from side to side; its middle is nearly on a level with the cartilage of the third rib; and its situation therefore corresponds exactly to the natural position of the right auricular appendix, as previously described. While the respiration proceeds naturally and quietly, this tumor is felt to give a slight pulsation and to become more tense, when the finger is lightly applied to the skin on its surface; and immediately afterwards the tumor recedes from the finger, or subsides, as it were, under it into the deeper parts, in a direction from above downwards and from right to left. If one finger be lightly laid upon this tumor, and another finger of the same hand be more firmly pressed on the region of the apex of the heart, the antecedence of the pulsation in the tumor to the apex-beat may be distinctly perceived; and it may, at the same time, be ascertained that the subsidence of the tumor and the pulsation of the apex of the heart are more nearly synchronous.

2. If, again, the finger be firmly pressed into the lower angle of the fissure, in the region occupied by the right ventricle, a pulsation and motion can be felt which are synchronous with the apex-beat, as might be expected from the occurrence of the ventricular systole in those situations. The same results follow from observations conducted by means of the glass funnels and tubes, and by following the movements of the integuments with

* It is deserving of notice, that these observations are subject to a fallacy depending upon the circumstance, that, among moving objects of a considerable size, the eye is apt to give priority of time to the motions of the one upon which it more immediately rests. On this account it is best to employ small animals for the observations on the heart's motions.

the eye, as already explained. There can be little doubt, therefore, that the slight pulsation in the tumor indicates the occurrence of the contraction in the right auricular appendix, which is the latest part of the auricle to contract, and that the subsidence of the tumor is due in part, perhaps, to the emptying of the auricle, but probably in a greater degree to that of the right ventricle, by which the tumor is thus made to recede from the surface towards the deeper parts. I am inclined to think that it is mainly from the circumstance that some observers have failed to distinguish the first pulsation of the tumor which is antecedent to the apex-beat, and have looked upon the receding motion as its only action, that they have been led to confound this phenomenon with the ventricular systole. Such confusion is very liable to arise in the observation of M. Groux's case, if the finger be too firmly pressed upon the tumor; for then, if the finger be applied at the upper part, the aorta is felt; if at the lower, the right ventricle is perceived.

3. In the upper part of the fissure, or between the divided parts of the manubrium sterni and cartilages of the second ribs, a third pulsation may be distinctly felt when the finger is pressed firmly and deeply into the fissure. This pulsation is perceptibly double, or consists of two parts; of which the first, giving to the finger the feeling of expansive pressure, is exactly synchronous with the apex-beat; and the second, seeming more like a succussion or recoil, follows instantaneously upon the first. These motions take place in the ascending part of the aorta; the first being due to the propulsion of a column of blood into the vessel at the instant of ventricular systole; and the second, which is synchronous with the earliest part of the ventricular diastole, being produced by the elastic recoil or backwards shock of the blood at the time of closure of the semilunar valves. If one finger be placed lightly on the pulsating tumor, which I will now call the auricle, and another be firmly pressed down on the region of the ascending aorta, the antecedence of the auricular to the aortic pulsation is more apparent than is perceptible in comparing the auricular pulsation with the apex-beat.

We may, therefore, with proper attention directed to the fissure in M. Groux's case, when the heart's action is proceeding quietly and regularly, perceive a succession in the occurrence of these three motions, viz., auricular systole, ventricuular systole with apex-beat, and, lastly, aortic recoil, after which succeeds the slight pause of rest before the phenomena are repeated. The auricular appendix being the last part of the auricle to contract, and the apex-beat coinciding with the commencement of the ventricular systole, and the one motion running naturally into the other, it is not surprising that many have found difficulty in distinguishing their succession, and that some have even affirmed their absolute synchronism; but I believe the latter view has

most frequently proceeded from the impulse of the auricle having been overlooked, and the attention having been chiefly arrested by the more obvious second phenomenon in the tumor, viz. its subsidence.

It must also be admitted, that there is occasionally considerable difficulty, even with the greatest care, in satisfying oneself of the antecedence of the auricular impulse; and this leads to the same conclusion which I have already stated as deducible from the observation of the exposed heart of a mammiferous animal, viz., that there is usually no appreciable interval between the auricular and ventricular systole. I will not go the length of affirming, with M. Ernst,* that at all times the auricular contraction lasts as long as the ventricular one, and that they are to be looked upon as a single and continuous action of the heart, to be completed before relaxation succeeds in either part; for I think there is sufficient evidence from previous observations, that, in a quiet state of the circulation, the auricular contraction may be distinct from the ventricular, and that the auricular diastole may either accompany, or even precede the ventricular systole. This is abundantly obvious in the frog and other cold-blooded animals, and in the languid condition of the warm-blooded animal's heart; but I will admit, with Schiff, that it more frequently happens in the warm-blooded animal, that the auricular contraction is in part prolonged into the ventricular one. M. Groux's case appears to me to afford evidence of the same. I need scarcely remark that it gives no grounds whatever for the view so strangely adopted by some, that the auricular contraction follows immediately the ventricular systole.†

I have found, on the whole, that the most reliable method of determining the order of succession of the motions in M. Groux's heart is by sight. Placing him in the sitting attitude, inclined somewhat forward and to the right side, resting the elbow of his right arm on a table, and allowing a strong artificial light to fall sideways on the groove, so as to lengthen the shadows thrown by the elevations of the skin, I found that the pulsating parts were brought more fully into view than when he was sitting erect; and I had no difficulty in distinguishing three motions in succession, viz., 1st, the auricular in the middle; 2nd, the ventricular in the lower angle of the fissure; and, 3rd, the aortic or arterial in the upper part. It was also observed in the experiments made

* Virchow's Archiv. vol. ix., as quoted in the printed extracts from M. Groux's album.

† I may remark, in addition to what is said above, that the difficulty of determining with nicety the synchronism or succession of various motions occurring closely together, is greatly increased when we endeavour to do so from the signs furnished by different senses—as touch for one, and sight for another—or when we endeavour to compare the indications of either of these senses with the time of occurrence of the sounds of the heart.

with the sphygmoscopes, that there was a slight rise of the fluid in the one placed over the auricular appendix at the instant of its impulse, and this was antecedent to the rise of the fluid in that placed over the ventricle; but the fall in the tube of the instrument placed over the auricle was synchronous with the pulsation in the region of the ventricle.

I was not able to detect any of the reflux pulsation in the veins of the neck, that may be perceived in many thin persons at the instant of auricular contraction.

Among the more interesting phenomena to be noticed in M. Groux's case, is the process of filling the right auricle and ventricle with blood in the intervals of contraction. Immediately after the pulsation and subsidence are over, there may be perceived a gradual and regular swelling of the tumor, which begins at the border of the left half of the sternum, at the place towards which the subsidence was directed, and proceeding upwards and towards the right, restores the original prominence of the tumor before the repetition of its pulsation and subsidence. In the quiet state of the respiration, this swelling is seen to affect only that part of the tumor which corresponds in situation to the auricular appendix; but I think it may be doubted whether this phenomenon is an indication of the filling of the auricle alone. We know indeed with certainty, that as soon as the ventricular systole is over, blood passes into the cavities of both ventricles from the adjacent auricular sinuses and veins, and I am inclined to attribute a considerable share of the rising or swelling of the circumscribed auricular tumor to its being raised on the filling right ventricle—a circumstance which accounts for the oblique directions from left to right and downwards, and the reverse, in which the tumor alternately rises and falls. This is illustrated more completely by the interesting change which the tumor is observed to undergo when the temporary suspension of the respiration leads to the accumulation of blood on the right side of the heart. When M. Groux holds his breath for a third or half a minute, the tumor increases greatly in extent and prominence, enlarging principally in a downward direction, and thus filling all the lower part of the fissure. It may then be perceived, as already stated in an earlier part of this paper, that the tumor is divided into two parts by a groove or constriction showing itself through the integuments, and passing in a direction obliquely downwards from left to right. A glance at the accompanying sketch shows that this groove corresponds exactly in situation to the line of division between the right auricle and ventricle; and there can therefore be no doubt that the tumor, enlarged by the suspension of respiration, consists superiorly of the end of the small auricular appendix, itself full, and pressed forward by the sinus of the auricle, and inferiorly of the cavity of the right ventricle, which occupies the whole of the lower part of the fissure.

The extent to which this tumor may be dilated, without apparent great disturbance to the circulation, and still more, the rapidity with which it subsides on the respiration being recommenced, are very striking phenomena as exhibited by this case.

With regard to the impulse of the heart, M. Groux's case supplies the clearest evidence that the apex strikes the chest at the time of the ventricular systole, as observed to occur in the lowest part of the sternal groove or fissure. It also appeared that the apex-beat corresponded to the first part of the systolic contraction chiefly, and that as the ventricles emptied themselves by the propulsion of blood into the great arteries, the apex seemed to recede from the walls of the chest. Upon the cause of the impulse, M. Groux's case supplies no evidence of a different kind from that which may be obtained from the examination of any other person; but I may here remark, that it appears strange that any one who has felt the exposed heart of an animal during its actions, should have conceived it possible that so forcible an impulse as that communicated by the apex to the walls of the chest could be given by the heart, when in the soft and flaccid condition of its diastole; and this remark applies with greater force to the heart when in the hypertrophied condition. It must be obvious, according to what has been said in an earlier part of this paper, that it is only at the moment of systole, that the heart is capable of communicating the stroke to the chest; but as the heart speedily diminishes in all its diameters, by the expulsion of the blood from the ventricles, the stroke is given with greatest intensity at the commencement of the systolic action. Various attempts have been made to explain the cause of this impulse on hydraulic principles, by the recoil of the ventricle at the moment of the impulse being given to the columns of blood in the vessels, and so forth; but it is to be remarked, that although such causes may not be without some effect in contributing to the apex-beat, yet they are rendered, in a great measure, unnecessary as explanations of this phenomenon, by the fact that the heart of a warm-blooded, as well as of a cold-blooded animal, still continues to rise upon its base, and to project its apex forwards and upwards, after the vessels have been divided, and the blood has ceased to flow through the heart. We must, therefore, look for the main cause of the apex-beat in the arrangement of the muscular fibres of the heart itself; and upon this subject I would refer the reader to the very sound remarks and ingenious observations of Dr. John Reid in his Treatise on the Heart, already cited from the Cyclopædia of Anatomy and Physiology, Vol. ii. p. 605 et seq. At the same time I may remark, that it appears to have been ascertained by the experiments of Kurschner, that the ventricular systole is accompanied both by a rise of the apex forwards, and a slight rotation of the heart on a longitudinal axis from left to right, while the diastole is attended with a subsidence

of the heart, and a rotation in the opposite direction, or from right to left. And thus, as Hamernik has judiciously remarked, in rising from the lower situation at the sixth rib, on which the heart lies in its diastole, and passing towards the right side, it strikes the chest in the fifth intercostal space, at a place which is manifestly nearer the base of the heart than the sixth rib.

Harvey's observations on the exposed heart of the son of Viscount Montgomery, previously referred to, seem to lead to the same view. He states in the 52nd Exercise on Generation,* "We also particularly observed the movements of the heart, viz., that in the diastole it was retracted and withdrawn, whilst in the systole it emerged and protruded, and the systole of the heart took place at the moment the diastole or pulse in the wrist was perceived; to conclude, the heart struck the walls of the chest, and became prominent at the time it bounded upwards, and underwent contraction on itself."

In his work on Auscultation,† Skoda refers to observations which he made in 1846, on a child a few days old, affected with congenital fissure of the sternum, and in which the form of the heart could be traced, and its motions perceived through the integuments, in support of a different view of the nature and cause of the impulse of the heart's apex; but, as I think, on insufficient grounds: for it appears that in this case the heart's position was vertical, and, therefore, in some degree abnormal. Skoda remarked, that in systole the heart moved downwards and forwards, and in diastole, backwards and upwards; and he farther states that the impulse in diastole, was as forcible as that in systole, in which it seems probable there must have been some inaccuracy of observation, or misconception. These objections do not apply to Harvey's observations on the young Viscount Montgomery.

M. Groux's case has also afforded us an opportunity of witnessing the changes in the position of the heart's impulse, which are produced by the different degrees of inflation of the lungs; in which changes, however, it ought to be remarked, there is nothing peculiar in M. Groux, as very nearly similar observations may be made in any person. This was shown many years ago by Dr. C. Williams. By a very full insufflation of the lungs, the apex-beat, and apparently the whole heart, was made to descend in the chest below its usual level, to the extent of at least an intercostal space and rib, and by an opposite extreme expiration, the ventricular impulse was found to rise higher and higher from its usual place, until in the state of greatest collapse of the chest, it could be felt in the third intercostal space. Dr. Wm. Gairdner seems inclined, in the valuable remarks which he

* Sydenham Soc. edit., p. 384.

† Edit. of 1850, translated by Dr. Markham, London, 1850 note to p. 155.

has inserted in M. Groux's album, to attribute this phenomenon to the separation of the apex of the heart from its usual place, by the dilated condition of the right ventricle, which is produced by the prolonged expiration; but this explanation appears unnecessary, as the change may be very rapidly produced, and can be accounted for by the change in the volume of the lungs, the subsidence of the ribs, and the rise of the diaphragm, which we know, may, in extreme expiration, ascend to the level of the fourth costal cartilage.

The investigation of the sounds of the heart in M. Groux's case presented also considerable interest, but the length to which these remarks have already extended must prevent me from entering at any length upon the discussion of this subject. The sternal fissure presents a most favourable opportunity of examining the sounds of the aorta, which cannot in the normal condition be heard with the same distinctness; and certain phenomena have been noticed by several of those who have examined M. Groux with respect to a partial reduplication of the first sound, which promise to throw farther light on the apparently complex causes of the first sound.

For the auscultation of the sounds in the fissure, it is necessary to employ small stethoscopes, formed of glass funnels with flexible caoutchouc tubes adapted to them; and these, indeed, seem to answer the purpose of stethoscopic auscultation fully as well as the ordinary wooden instruments.

Dr. Williams, Dr. Wm. Gairdner, and others, observed that the first sound appeared to begin in the auricular systole, and to be prolonged throughout the whole of the ventricular contraction; and it was occasionally observed that a slight reduplication of this sound occurred, as if by the separation from the main part of it of a slight and short sound synchronous with the auricular systole. I noted this fact several times, but I could not determine with precision the circumstances in which it occurred. It seems not improbable that, in the auricular systole, some of the same circumstances which in the ventricular contraction produce the prolonged first sound, may cause a slight auricular sound—so slight, that it is usually not heard, or is lost in the more distinct and prolonged ventricular sound. I do not stop to consider the causes of the production of this sound in this place, but I will merely remark that a careful observation of these phenomena in M. Groux and in other persons, may possibly lead to a more accurate discrimination of the causes of the systolic sound.

The exact synchronism of the second or short sound, with the time of closure of the semilunar valves of the aorta and pulmonary artery, could with great convenience be observed in M. Groux, because of our being able at the same time to distinguish by feeling the double motion in the aorta—caused, the first by the systolic dilatation from the ventricle; the second by the recoil of the vessel

at the commencement of the ventricular diastole, and the closure of the semilunar valves. If any farther evidence were required with respect to the cause of the second sound, after the conclusive experiments of Hope and Williams, and of the Dublin Committee of the British Association, it would be afforded by these observations on the aorta in the upper part of M. Groux's sternal fissure. On pressing the small funnel or stethoscope firmly down into the groove, in the situation of the ascending aorta, while we could feel distinctly the two motions of expansion and recoil of the artery, the two sounds were also distinctly heard; the first, or ventricular one, communicated through the column of blood, being somewhat modified; the second, being nearly the same as it is usually heard over the sternum, in the region of the semilunar valves.

On the whole, then, I conclude that the normal succession of the heart's actions is clearly indicated in the case of M. Groux, by pulsations and motions in the sternal groove, which correspond to the following phenomena:—The contraction of the right auricular appendix; the systole of the right ventricle; the subsidence and emptying of these two cavities, and their subsequent gradual filling with blood; the expansive dilatation and subsequent recoil of the first part of the aorta, corresponding respectively to the ventricular systole and closure of the semilunar valves. These phenomena, which are to be observed in M. Groux in a manner which is impossible in the natural state of the parts, taken along with the observations which may be made in other parts of the chest, in the same manner as in other persons, are not only not inconsistent with the generally received opinions of physiologists in regard to the heart's action, but appear to furnish important direct evidence in support of them.

The case is also interesting, as directing our attention more immediately in the human subject to a circumstance which can be well observed in the exposed heart of warm-blooded animals: viz., the extreme rapidity with which the auricular contraction passes into the ventricular systole, so that at many times no perceptible interval exists between them, and probably at others the auricular contraction is prolonged into the ventricular one.

It may not be out of place here to mention, along with the foregoing remarks on the heart's action, a fact which was elicited in consequence of some observations which fell from Dr. Watson, the president of the Medico-Chirurgical Society, on the occasion of M. Groux presenting himself before that society and the Medical Society of Glasgow. Dr. Watson having quoted from the manuscript notes of the late Dr. Cleghorn, the history of a case which had come under the observation of that accomplished physician, of a man possessing the power of voluntarily putting a stop to the heart's action, M. Groux had, in company with some medical men of this city, made experiments relating to this

subject, and M. Groux fell upon a method by which he found that he was able at will, and with great facility, to cause the heart's action to cease for a period of more than fifteen seconds. The plan was merely to take a very deep inspiration, and, to render it complete, it seemed best to take the inspiration in two times, and immediately afterwards to close the glottis, and throw the muscles of expiration into sudden and strong action, so as to compress the chest on all sides. The action of the heart immediately ceases; and I may state that, if it does not cease on the instant, it is impossible to stop it by any renewed or continued efforts at the same time: the inspiratory effort must be begun anew. I found that I could succeed readily in the same experiment, and others, I believe, found they could, with equal facility, cause the heart's action to cease for a short time by the same means. I refrain from entering here on the consideration of the cause of this phenomenon. The effect of deep inspirations and expirations in causing variations in the strength and frequency of the pulse is well known to most physiologists.

I am also precluded, by the length of this paper, from making any detailed remarks on the condition of the lungs, and the phenomena of auscultation, in M. Groux's case. I refer the reader to the statement made in an earlier part of the paper with respect to the hernial projection of the upper and anterior portion of the right lung, produced by coughing. It is obvious that the depression of the integuments in the fissure, during inspiration, depends upon the circumstance, that when the inspiratory effort is rapid or great, the expansion of the walls of the chest is not fully or immediately compensated for by the filling or dilatation of the lungs, the elastic substance of the lung offering a certain amount of resistance to that expansion; and, therefore, just as the external air would enter the chest at a wound of the thoracic wall in similar circumstances, so the soft and yielding integuments in the fissure are thrown inwards by the atmospheric pressure.

The sudden protrusion of a portion of the right lung through the upper half of the sternal fissure, and up into the neck, which forms in M. Groux's case a very remarkable accompaniment of the act of coughing, is explained with equal facility: for when the walls of the chest are suddenly collapsed by the action of the muscles of expiration, and the glottis is opened at the same instant, the lungs are compressed over their whole surface, and the air within them, not finding vent with sufficient rapidity through the trachea, throws the pressure on any part of the lung, such as that situated in the fissure on the right of the mediastinum, which is free to move or to expand in a greater degree than the rest. It is not improbable that this effect may be increased by an emphysematous condition of the portion of the lung which protrudes in M. Groux's case.

It was my intention also in this place to have added some remarks on the peculiar modification of the motions of the ribs and divided portions of the sternum, under the action of the intercostal, pectoral, and other muscles; but I can only now advert to this subject in the shortest possible manner. With respect to the ordinary acts of inspiration and expiration, there does not appear to be anything different in M. Groux from what is known in other persons, excepting perhaps in the greater proportional strength and fuller action of the sterno-mastoid, sterno-hyoid, sterno-thyroid and great pectoral muscles. It was more especially obvious that in all strong efforts of inspiration, the sterno-mastoid muscles afforded important assistance in raising the sternum and expanding the chest. It appeared also that the ribs possessed a more than usual degree of mobility at their vertebral articulation, so as to be capable of undergoing very considerable elevation and rotation.

It appeared farther that in M. Groux the sterno-clavicular articulation is much firmer than usual, so that very little lateral motion was possible in this joint (but without ossific union of the bones), and thus any pressure exerted on the outer end of the clavicle produced its full effect on each of the sternal segments. It is thus, we shall see, that the clavicle becomes in M. Groux the most important means of producing the closure of the fissure by muscular pressure acting on that bone.

In order to separate the edges of the sternum, or widen the fissure, M. Groux places his hands against one another before him, or one on each side of his head, and then throws the muscles of the arms, shoulder, and back into action, so as to press the hands firmly against each other, and to fix the shoulder and humeri firmly outwards; the great pectoral muscles, and the clavicular part of the deltoid muscles then acting forcibly, draw the segments of the sternum, ribs, and clavicle outwards, and dilate the sternal groove to the extent of from two to two and a half inches. This is nearly equivalent to an action which throws the shoulder outwards, and thus causes the pectoral and deltoid muscles to act from the arm as their most fixed point. M. Groux was also able to dilate to some extent the groove on one side, when the hand was fixed. The serratus magnus may also probably assist in this action.

In order to approximate the edges of the fissure, M. Groux locks his hands together, and makes an effort to separate them. In this effort all the posterior muscles of the scapula are thrown into strong action, the trapezias, rhomboids, supra- and infra-spinatus, the middle and posterior parts of the deltoid, latissimus dorsi, &c.; but the great pectoral and anterior part of the deltoid muscles remain flaccid. This is equivalent to an action which tends to bring the shoulder inwards, and the clavicles which are firmly articulated with each half of the sternum are thus the

means of pushing together the bony margins of the fissure. It seems probable that the scapula, by pressing on the ribs, may also assist in this closing action.

The shoulder, therefore, and the humerus at its upper part, are the fixed points in the two cases—in the effort to open the fissure, tending outwards, so as to enable the pectoral muscle to draw the half sternums outwards; in the effort to close the fissure, tending inwards, so as to press inwards the clavicle, and with it the sternal edges of the fissure.

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