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LECTURES
ON
THE GRAPHIC METHOD IN THE EXPERIMENTAL SCIENCES, AND ON ITS SPECIAL APPLICATION TO MEDICINE.

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I.

WHEN we follow the development, which is now so rapid, of the experimental sciences, we observe that each new progress is the result of some improvement in the methods employed. The telescope, the microscope, the chemical balance, the galvanometer, etc., are in the hands of every investigator. No one would presume to substitute the powers of his unaided senses for the employment of these marvellous apparatuses, to which are due nearly all the modern conquests of science.

By a singular exception, the study of living beings was for a long time limited to unaided observation. Thus the physiologist and the physician, while displaying the greatest sagacity in the observation of the phenomena of life, only arrived at imperfect notions. By the side of the exact sciences, physiology and medicine seemed to have but little precision. People had even come to deny that the acts of life were subject to rigorous laws, because these laws could not yet be discerned in it.

Skilfully practised experiments on living animals, however, showed that in animals, as in the inorganic world, a phenomenon can always be reproduced, identical with itself, when the experimenter places himself under well determined conditions; on the other hand, the precise means of medical diagnosis, auscultation and percussion, permitted skilled clinical observers to determine with admirable precision the seat and the extent of certain lesions. The possibility of really scientific physiology and medicine could thus be conceived.

But in the laboratory, as at the bedside of the patient, the skill of the individual, his practised tact, and the subtlety of his perceptive powers, played too large a part. To render accessible to all the phenomena of life—movements which are so light and fleeting, changes of condition so slow or so rapid, that they escape the senses—an objective form must be given to them, and they must be fixed under the eye of the observer, in order that he may study them and compare them deliberately.

Such is the object of the graphic method, of which I shall have the honour of showing you some of the applications.

Great names are attached to the origin of the graphic method. In England, Thomas Young inscribed upon the surface of a revolving cylinder the movements of a vibrating rod, and conceived the possibility of recording, according to the number of its vibrations, extremely short intervals. James Watt inscribed also on a cylinder covered with paper the movements of the piston of a steam-engine. In France, Poncelet and Merdy created the celebrated machine which inscribes automatically the laws of the fall of bodies. This apparatus has become classic, and every one has seen with delight a weight armed with a pencil fall vertically, tracing on the revolving paper a parabola affording the graphic expression of its uniformly accelerated motion.

German physiologists introduced the graphic method in the study of certain movements. Ludwig inscribed the oscillations of a manometer applied to the arteries of an animal. Volkmann and Helmholtz obtained curves of the muscular contractions excited by electricity. Now, this method is greatly extended; the physicist, the physiologist, and the astronomer have recourse to its employment. Inscribing apparatuses are continually undergoing modifications and improvements; and their indications, by the precision which they present, show that there is no movement so feeble or so rapid but that it can be inscribed, and consequently be exactly determined.

In order to understand well the bearing of the graphic method, the motion which it serves to register must be considered from a general point of view. All motion, then, consists in a relation of space to time. To know the trajectory of a body which is displaced, is not to know the movement which that body has accomplished; for it may have made its way along this trajectory by a motion either slow or rapid, uniform or interrupted. The graphic curve of a movement furnishes us with the double notion of time and space; it characterises completely the act which it represents.

Graphic traces are too generally familiar to make it necessary to dwell on the interpretation of them. A very simple example will serve to show at once the action of the apparatus and the signification of its tracings.

The heart of cold-blooded animals preserves its pulsation, we know, for a very long time after it has been separated from the body. We can inscribe the movements of the heart of a frog in the following manner. The organ, detached from the body, is placed (Fig. 1) on a

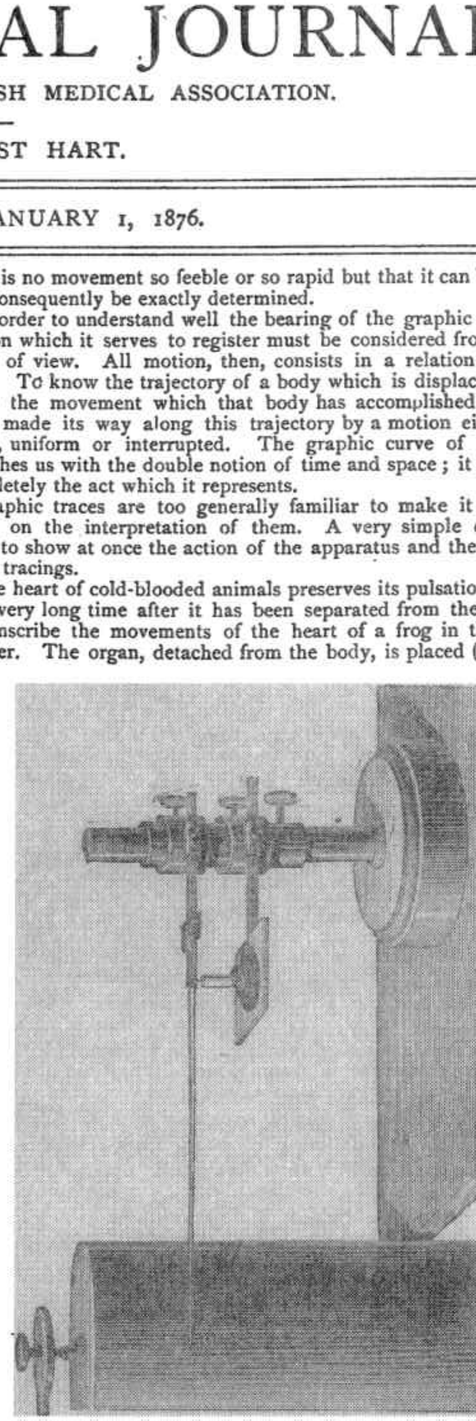

Fig. 1.—Myograph of the Heart, or simple Cardiograph.

little stage, and a light rod of elder pith is laid on the ventricular mass; the rod articulated with a little lever transmits to it rhythmical uprisings, according to the frequency of the acts of cardiac systole. The lever, then, is seen to execute alternating movements as the ventricle moves, and the amplitude of these is augmented in proportion to the length of the lever employed, which makes them more easily recognised by the sight than if you were to examine the heart in a direct manner. But we have here as yet only a visual impression incapable of informing us with sufficient precision concerning the phases of these alternating movements, and the changes which may be produced in them by fatigue, variation of temperature, the action of poisons, etc. To judge of these modifications, let us inscribe them. For this purpose, we terminate the lever by a fine and flexible point, which rolls against a cylinder covered with smoked paper. This cylinder revolves and presents constantly to the writing point a different part of its surface. When the cylinder has finished its revolution, we have collected a first tracing (Fig. 2, line at bottom). To inscribe a second line, we lower the cylinder a little; we proceed in the same way for a third line; and in the end we obtain a series of superposed tracings (Fig. 2) which may be compared one with the other, and submitted to measurement, and brought to rule and count. We see thus that, as the effect of fatigue, the systolic acts of the heart become feebler and fewer.

Under the action of certain poisons, we should observe irregularities in the amplitude and the rhythm, and we should have a much more exact notion of these perturbations than by direct observation, since we could compare the amplitude and the duration of each of the systoles of the heart.

This very simple experiment allows us to approach the examination of a more complex case, that in which it is our business to inscribe the pulsations of the heart of a man or of an animal, and to transform into a detailed curve that fugitive impression which the finger experiences in exploring the præcordial region: a sensation which makes us believe in the existence of a shock or blow against the walls of the chest. The instrumentation must here be a little more complicated. We have to transmit to a distance the cardiac movement, in order to send it to inscribe itself by means of a lever, as in the preceding case. This transmission is effected by pneumatic tubes.

Imagine two capsules or drums of metal closed above by an India-rubber membrane; these drums communicate with each other by a tube more or less long, according to the distance to which the movement has to be transmitted, and the whole is filled with air. If you press upon the membrane of one of these drums, the air driven from it will pass into the other, and will lift up the membrane. Leave off pressing upon it, and the air in the second drum will re-enter the first, and the membranes will resume their horizontal positions.

Suppose that one of these drums be placed under an inscribing lever at the spot where the heart of the frog was placed in the preceding experiment, this lever will inscribe all the movements of the finger pressing with variable rhythm on the membrane of the other.

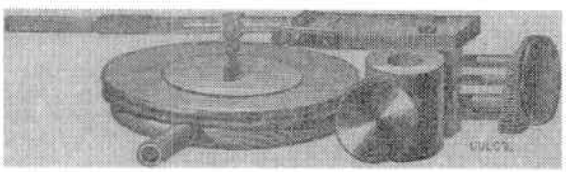

Fig. 3.—Drum and Lever for receiving and inscribing a movement which is transmitted to them by the air. The horizontal lever, broken across in the drawing, is prolonged more or less according to the amplification which it is desirable to obtain, and is terminated by a writing point.

But the instrument for exploring movements must present a different arrangement according to the particular cases. To collect the pulsations of the heart, we give to the exploratory drum the following form.

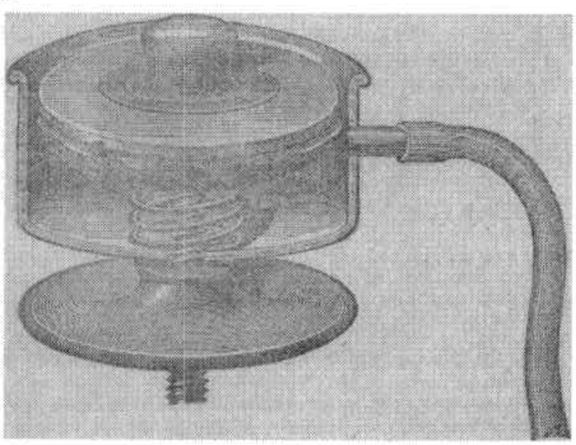

Fig. 4.—Exploratory Drum for the Pulsation of the Heart in Man and Animals.

The drum and membrane lodged in a cylinder of wood carries on its elastic surface a little button of cork, which projects externally. This button is applied with care to the region where the heart is felt to beat. The movements communicated to the membrane, and to the air of the exploratory drum, are propagated by a pneumatic tube to the receiving drum, and inscribe themselves on a smoked cylinder or any other analogous apparatus. Fig. 5 shows one of the arrangements which may be adopted for the inscription of a movement transmitted to a distance.

When, now, we have obtained the tracing of a pulsation of the heart, we conceive that its movements are much more complicated than would be believed, according to the sensation which the finger experiences in palpating the cardiac region.

Fig. 6 shows this form in the condition of health. It would present the greatest difficulties in interpretation, if it had not a striking resemblance to the pulsation which we obtain from the heart of the mammal. Now, in animals, we can introduce into the cavity of the heart special exploring instruments, which, transmitting the movements of the different cardiac centres, allow their inscription at the same time with that of the external pulsation. By disposing three inscribing levers one above the other, in such fashion that the three pens shall be in the same vertical plane, we obtain a triple tracing (Fig. 7), in which the superior line *o* represents the movements of the auricle, *v* those of the ventricles, while *p* corresponds to the cardiac pulsations, and is very analogous, as may be seen, to the Fig. 6 obtained from man.

Without entering into technical details of these experiments, we understand easily that the exploration of these different cavities of the heart informs us concerning the signification of all the details of the curve furnished by the external pulsation. It has thus been possible to ascertain that the one undulation corresponds to the closing of the auriculo-ventricular valves, the other to that of the sigmoid valves; that the period during which the curve is highest measures the duration of the systole of the ventricles, whilst the period of depression of the tracing expresses their relaxation.

The arterial pulse, long since inscribed by means of a special instrument known as the sphygmograph, may be transmitted to a distance, like the heart-pulse, and self-inscribed at the same time with it. Two tracings are thus obtained, in which the cardiac action may be compared with the effects which it produces in the arterial circulation, which is of great importance when the movements of the heart are altered in their rhythm or disturbed in their mechanism. Fig. 8 shows the exploratory instrument for the pulse which allows this transmission to a distance. Fig. 9 is the tracing of the pulse in lead-poisoning.

Fig. 9.—Tracing of the Radial Pulse in a case of Lead-poisoning.

Sometimes the graphic method alone allows us to perceive certain movements of which we have no knowledge. Thus all our organs in which the blood penetrates through arteries with a rhythmic movement, are the seat of rhythmic changes of volume which the eye cannot see, and which the hand does not feel. It has long been known that, when we plunge the hand into a vessel full of water, the level of the fluid, if it be reduced to a column of small diameter, presents rhythmic variations. These movements can be inscribed. Dr. Charles Buisson some time ago carried out this experiment; and Dr. Mosso of Turin has constructed also an instrument intended to indicate the changes of volume which are presented by an organ submerged in a fluid. His apparatus shows the incessant mobility of volume of the organs much better than changes of colour and of temperature of the tissues could do; it reveals the thousand influences which, causing the smaller vessels to contract or relax, regulate the local circulation in the different points of the economy.

Dr. François Franck, taking up anew the experiments which Buisson had only roughly commenced, has just terminated a series of studies on the influences which regulate local circulation. The tracing in Fig. 10 shows the perfect resemblance of the movement of erectility of the organs to the phenomena of the pulse; it reveals besides the effects produced during and after an effort of respiration.

The rapidity of the current of blood in the arteries may also be translated by a graphic curve. Vierordt had already undertaken the inscription of this movement, and Chauveau had solved the problem in a much more satisfactory manner by inscribing the oscillations of a needle implanted in the arterial wall, and plunging into the interior of a vessel. For this purpose, we may employ an instrument founded on the use of the tubes of pitch, of which engineers avail themselves to measure the rapidity of watercourses. This instrument, by means of a special arrangement, allows the transmission to a distance of the movement which expresses the different rapidity of the currents of the blood; and, as the physiologist is already in possession of instruments which inscribe the arterial pressure by combining the two orders of tracings, we obtain precious information concerning the state of the arterial circulation. Although this kind of study, which is especially physiological, has not yet, to speak accurately, its medical applications, it deserves to attract our attention for a moment.

It may be said that, up to this time, the conditions of the arterial circulation have been incompletely determined; the employment of the manometer becoming extended in physiology permits us, it is true, to ascertain if the pressure rise in the arteries, or if it fall. But on what does this change depend? Is it due to a modification of pressure arising in the force of the heart? or to a change in the diameter of the small vessels, which allows the blood to pass more or less rapidly from the arteries to the veins? This question the manometer alone cannot solve.

A familiar illustration will well explain the difficulty which is offered by the interpretation of the changes of arterial pressure. If we learn that the level of a river is raised, we cannot from that information alone learn if the increase be produced by abundant rains which have passed more water into the river, or if it be the effect of a barrier placed across the current of the stream. To judge of what has happened, we must know further if the current have become more rapid, or if it have slackened. A *simultaneous* increase in the rapidity and the height of the water indicates a more considerable afflux; but, if the increase be accompanied by a slackening of the current, it is due to a barrier existing *en avant*.

The conditions are the same in the circulation of the arterial blood; here the pressure of the blood corresponds to the height of the level. The changes of pressure alone do not suffice to determine the state of the circulation. But, if we know at once the rapidity and the pressure of the blood, we have all the elements of the solution of the problem. When the double tracing shows that the rapidity and the pressure have varied alike, it is to a change in the force of the heart that we must look for the cause of this double variation; but, if the pressure and the rapidity vary inversely to each other, it is in the small vessels that we must look for the cause of the change.

Fig. 11 shows a double tracing of the rapidity and of the pressure; we see there that the curve of speed is depressed, while that of pressure is raised. It is, then, an obstacle to the flow of the blood which had occurred in this case.

Another application of the graphic method of the study of the movements of the blood consists in inscribing the movements of the waves which the heart sends into the arteries. These waves, entirely subject to the laws of hydraulics, traverse the interior of the vessels, passing from the heart to the extremities. According to the rapidity of their progress, and according to the space over which they have to pass, the pulse of an artery is more or less behind the systole of the heart which produces it. The knowledge of these movements of the blood-wave is indispensable for the theory of the dicrotic pulse, in which the double beat which the finger ascertains corresponds to the two successive waves which flow one after the other to the interior of the vessel.

To follow the movement of the waves to the interior of an artery or of an elastic tube filled with fluid, we arrange along the course of the vessel or of an elastic tube filled with fluid a series of exploratory instruments analogous to those already described. Each of these corresponds to a writing lever, and the series of levers is placed as usual, so that the pens may be exactly superposed. In passing under each instrument, the wave produces an elevation of the corresponding lever. Then we see the levers begin to move one after the other, and to trace a series of curves of which the interval of succession allows the exact measurement of the rapidity of the wave. When each of the levers experiences a series of successive oscillations of decreasing intensity, it is because a series of waves has been produced as the sequel of a single penetration of fluid into the tube. Such is the phenomenon which gives rise to the dicrotic pulse.

But I have insisted perhaps too much, in this limited address, on the application of the graphic method to the study of the circulation. My object was to show that almost all the movements of the blood may be inscribed, and consequently measured, with extreme precision. If I have attained this object, allow me to pass to other applications of the method, and to approach other movements not less important for the physiologist and the physician to know and to understand.

FURTHER OBSERVATIONS
ON
HARE-LIP AND CLEFT PALATE.

By SIR WILLIAM FERGUSSON, Bart., F.R.S.,
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In April 1874, my experience of the supposed new operation extended to only three or four cases. It seemed to me so likely to be of service in cases which I had abandoned in despair, that I felt it a duty as well as a pleasure to let my professional brethren know as much as I could communicate at that early date. The number in which I have now had similar experience amounts in all to eighty-two. This experience is larger than I could have anticipated in less than twenty months' time, but it may be considered the more valuable on that account, both as regards numbers and freshness of work. The results have been such as to induce me to consider the process which I recommend as a vast addition to our surgical resources in this special department. In the above number (eighty-two) fifty-six are cases treated for the first time; the remainder are instances where further manipulative interference has been required, including examples of holes, large or small, in the hard palate, which I had left as beyond help from surgery excepting by means of an obturator, associated with defect of teeth in front. In two of these, I consider the proceeding to have entirely failed. In these, each patient was only four years of age, delicate, and with a wide gap. Although mechanical approximation in the middle was satisfactory, union by the first intention failed. Inflammation seemed greater than could be desired, and slight necrosis took place in each, so that the gap was left even wider than before. In several instances, particularly in the early operation before precision in the use of the chisel had been acquired, one or possibly two small pieces of bone came away necrosed, but, considering how the chisel has been freely used in some of these cases, I have been astonished how little damage has been done to bone. In some instances, union failed both in hard and soft parts from unaccountable causes, just as happens, from time to time, when the soft palate alone is involved; this is seen sometimes even in favourable cases of hare-lip, but my success has been such that I feel great confidence in the successful result of almost every instance of well-performed operations of the sort. Where holes and slits have been left either in hard or soft palates, or where union has been defective in the uvula, such defects have usually been amended at one or more subsequent operations, to which patients have readily submitted, owing to former immunity from pain under chloroform.

In one instance, an attack of scarlatina thwarted my best efforts; and in another, unhealthy inflammation arose after three operations, and ulceration marred, in some respects, the completeness of the proceedings.

The cases in the hard palate, which have given me most trouble, have been where the vomer has been extensively attached to one side. In most of such cases the vomer diverges to one side. The palate can here be as readily split as if no vomer were present, but two objects of the splitting cannot be obtained; the margin of the palate can scarcely be drawn towards the middle, and the flap cannot be brought downwards to meet its more movable fellow. This has been a cause of failure which I did not at first appreciate; but subsequently I have achieved success by chiselling on one side, and paring off the soft tissue from the hard palate, on the side where the vomer was, and stitching it to the more substantial flap on the other side, thereby combining the new and old processes, with benefit to the patient, and some additional credit to our surgical resources in this locality.

Mr. Mac Cormac has most obligingly laid before me most of the German authorities on the subject. Although Dieffenbach suggested the operation in 1826, no case of his has been recorded. It seems to have been put into execution for the first time in 1834, by Bonn, with success. Langenbeck, from 1849 to 1856, operated in three cases, but definitively abandoned this proceeding. Two cases of openings in the hard palate, from syphilis, have been operated on by Bühring on similar principles, but unsuccessfully. Between 1826 and 1856, some half-dozen cases have been recorded by German authorities, in which the hard palate seems have been cut by saw, knife, and chisel; but altogether the circumstances may be considered so different from those which I have described within the last twenty months, that there is but little resemblance between them. Muscular action, particularly that of the levatores palati, is not even referred to; the use of anæsthesia or a gag

* Concluded from page 773 of number for December 25th, 1875.

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