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LECTURES

ON

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

Delivered at the Medical Congress in Brussels, September 21st, 1875.

By M. MAREY,
Professor in the College of France.

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

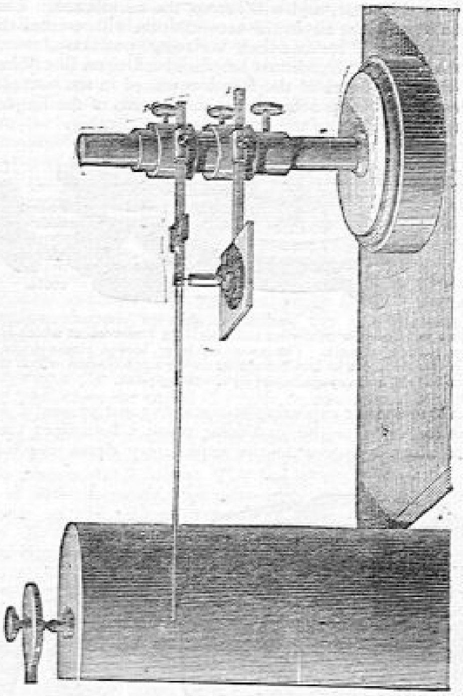

Fig. 1.—Myograph of the Heart, or simple Cardiograph.

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.

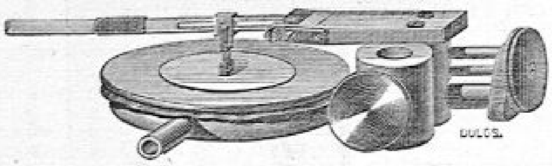

Fig. 3.—Drum and Lever for receiving and inscribing a movement which is transmitted to them by the air. The horizontal lever, broken across in the drawing, is prolonged more or less according to the amplification which it is desirable to obtain, and is terminated by a writing point.

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.

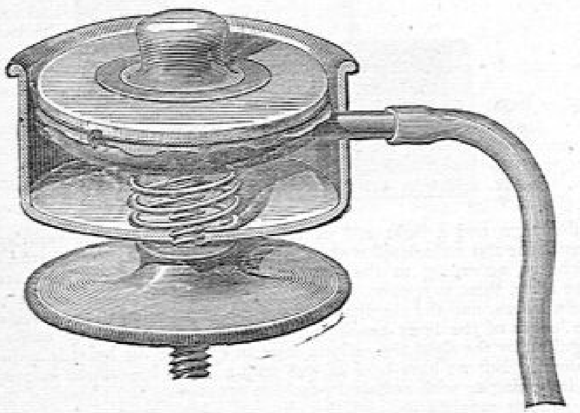

Fig. 4.—Exploratory Drum for the Pulsation of the Heart in Man and Animals.

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.

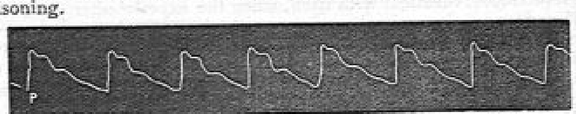

Fig. 9.—Tracing of the Radial Pulse in a case of Lead-poisoning.

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.,
Surgeon to King's College Hospital, etc.*

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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II.

THE respiratory movements, the action of muscles, the rapidity of transmission of the sensory and motor nervous agents, the normal or abnormal motions in walking, the buccal or pharyngeal motions which take place in phonation, all these varied acts do not interest the physiologist only, but are capable of furnishing valuable materials for enlightening the diagnosis of disease. Some of these phenomena entirely escape our senses; all are appreciable by the graphic method, and, as soon as they are thus inscribed, lend themselves to the most precise methods of estimation.

In order to inscribe the movements of respiration, Vierordt put the patients in the horizontal position. A lever rested on the sternum, and inscribed the movements of dilatation and retraction of the chest. It is more convenient to have recourse to the method of transmission already indicated for the study of the movements of the heart. A special "explorer", adapted to a chest-band, sets in motion at a distance an inscribing lever, and gives a trace in which the rise corresponds to expiration, and the fall to inspiration. In the physiological condition, the existence of a certain rhythm is observable. If, then, we vary the resistance which the air encounters on entering the chest, or that which it encounters during expiration, we cause a similar variation in the rhythm of the movements of the thorax. Thus prolongation of expiration reveals the existence of an obstacle to the expiratory forces. If, on the contrary, it be inspiration which is prolonged, it may be concluded that there is an obstacle to the introduction of air into the lungs.

Physicians now no longer consider pathological cases as a reversal of the laws of physiology. They are not astonished to see dyspnœa translated by changes of the respiratory rhythm—changes which are produced in the sense above indicated. The respiratory tracings obtained in asthma seem to show that there exist at least two distinct forms of this malady: one appears to be associated with spasm, and the other with atony of the bronchi.

It would be premature to put forward on this subject affirmations of too absolute a character; further researches can alone lay the foundations of the semeiology of the respiratory movements. One point seems, however, now well established; that is, that the functions of the heart and lungs may undergo, by muscular exercise frequently renewed, profound modifications. When young recruits are subjected to progressive training in the military gymnasia, it is observed at the outset that the movements of the heart and those of respiration are strongly accelerated under the influence of running. The movements of respiration have then very little amplitude, and are renewed as often as one hundred times in a minute. At the end of some months' training, the same subjects, after having run, give traces of the heart and respiration in which all perturbation has disappeared. The movements of the thorax are no longer accelerated; and, far from presenting a diminution of amplitude, they are, on the contrary, deeper than in the state of rest.

The inscription of muscular acts has profoundly modified physiological theories relative to the production of movement. Thus, in tetanus caused by strychnia, and in that which is provoked by induction-currents frequently repeated, the myograph reveals the existence of vibratory movements which the eye could not perceive. This instrument shows that the shortening of a tetanised muscle is produced by the fusion of a series of little elementary movements which we call shocks, and no one of which has time to be completed before the next one follows. It may be proved that voluntary contraction is a complex act, like tetanic spasm; and the energy of the effort developed by a muscle increases in proportion to the frequency of the shocks which are produced during its contraction.

As every muscle swells at the same time that it is shortened, this swelling may be explored by means of a special apparatus, and the shocks of the contraction of the muscles in man may be inscribed. It is thus seen that pathological convulsions cannot any longer be grouped in two classes, according as they are tonic or clonic. Every tonic convulsion, in fact, is constituted by a series of shocks, which vanish from our senses in the shortening of the muscles; but the tracing which is obtained by inscribing these acts reveals the existence of multiplied shocks more or less completely fused.

Another application of the myograph to man permits us to measure the rapidity with which the nervous motor agent is transmitted. The celebrated experiment of Helmholtz may be easily repeated on man by inscribing on a rapidly rotating instrument the instant at which a nerve is excited, and that at which movement appears in the corresponding muscle. Without asserting that this determination should be ranked amongst the ordinary methods of medical diagnosis, it may be hoped that it will throw light on the pathological physiology of the nerves and muscles. When a movement is produced after sensitive impression, whether from reflex action or as a voluntary manifestation of a received impression, it allows the duration of the nerve-transmissions of mental operations to be appreciated, by inscribing itself on the paper at the instant when the sensitive excitation has occurred, and that in which the motor manifestation has shown itself. We record an interval of time between these two acts which our senses would but ill appreciate, but which is revealed with exactness by the graphic method. In the measurement of the sensory nerve transmission, this interval is seen to increase in proportion as a more distant point of the nervous centre is excited; that is to say, in proportion as the nervous agent has to traverse a greater length of the sensory nerve in order to reach the centres. In the same way, in the measurement of the cerebral actions, the delay between the irritation and the movement which follows it is seen to increase, in the same proportion as the subject of the experiment performs a more complex intellectual operation between the impression he has received and the signal by which he must indicate that he has understood. The beautiful researches of Donders on the measurement of the cerebral actions are too well known to render it necessary to recall them in these pages; besides which, it would be very difficult to briefly set forth those bold and successful attempts at introducing exact measurements into the domain of physiology. In the preceding experiments, we treated of very short periods of time, measured with very great precision; and for this purpose physical science possesses a very powerful means—chronography—of which the original idea is due to Thomas Young, but which in later years has been greatly perfected. The essence of the method consists in inscribing on a smoked cylinder the vibrations of a diapason regulated to a certain frequency—say one hundred vibrations to the shock. The tracing of the diapason is formed by a wavy line, of which each undulation, more or less amplified, according to the quickness of the rotations of the cylinder, represents a hundredth part of a second. If two signals be simultaneously inscribed on the cylinder, of which the one corresponds to the commencement and the other to the end of the time to be measured, between these two signals a certain number of vibrations may be counted, expressing to how many hundredths of seconds this short interval of time corresponds. Thanks to the constant progress of chronography, we are now able to estimate periods which do not attain the hundredth part of a second, and even less. In this division of time there is, so to speak, no other limit than that self-imposed by experiment, when it seems to have attained a sufficient degree of precision.

Besides the direct employment of the diapason, which is sometimes not very convenient, the use is sometimes substituted of small instruments called electric chronographs, which, being light and portable, are easily arranged in connection with other inscribing levers in the different experiments. Certain electro-magnetic apparatus serve to produce signals. Their action is so rapid, that they are able to furnish more than five hundred different signals to the second. By means of this instrument, the vibrations of the larynx in speaking or singing are inscribed; and as, on the other hand, with special explorers, the movements of the lips, of the velum palati, and of the air which escapes during the emission of sounds can be inscribed, the study of the mechanism of phonation acquires an astonishing degree of precision. The linguist, the physiologist, and the physician, alike find interesting subjects for study by the use of this method.

I regret that time is wanting for me to show the application of the graphic method to physiology and to medical diagnosis; but, before concluding, I wish to show this method in a less special aspect, and to express my convictions as to the great future which is reserved for it throughout all the experimental sciences. The most perfect expression of a phenomenon is a curve, which, by divers inflexions, expresses the successive changes which have occurred. When a physicist or a meteorologist wishes to set forth in a satisfactory manner the result of a series of meteorological observations, he traces a curve in accordance with the numerical values he has previously obtained. This curve, which rises, falls, or remains stationary, shows what has really taken place much more clearly than a column of figures, which is tedious and fatiguing to read down. The comparison of the two curves is as it were instantaneous; their identity and their dissimilarity strike the eye at once. The sum of every kind of observation can thus be expressed by curves: changes, pressure, weight, or bulk, or variations of intensity of any kind of force. Still more, all kinds of statistics lend themselves to the use of this method, and thus yield to the first essay results which could only be disengaged by a long and assiduous study. Therefore the use of the curve becomes daily more widely diffused, though not with sufficient rapidity for the wishes of those who realise the sum of its usefulness. How is it possible not to anticipate with impatience the day when long and obscure descriptions will give place to satisfactory representations? All who occupy themselves with experimental study or observations, readers overwhelmed and invaded by the accumulation of written documents, the economist, the statistician, the financier, the statesman, who accumulate around them volumes full of figures, one of these days will find, in one atlas containing some luminous curves, the whole essence of these crude materials. If the graphic method, however, possesses such great advantages from the aspect of the exposition of observed facts, how great is its superiority when the phenomenon of which it gives up the tracing belongs to those which entirely escape the perception of our senses! Here there is no longer any intermediary between the act and its graphic expression. Transformed into inscribing apparatus in meteorological observatories—the barometer, the thermometer, the hygrometer—incessantly determine the state of the atmosphere. Patient, conscientious, infallible, these instruments do what would be impossible to a legion of observers. Formerly, the boldest imagination could not have dreamed that the velocity of a cannon-ball could be seized at all points of the trajectory. This important problem, however, is now solved, and still greater velocities are determined at the present day. The graphic method is equally applicable to the measurement of extremely slow movements. We do not see the growth of a plant; but we can obtain the tracing of its increase, and record that, at certain hours and under certain influences, vegetation is accelerated or retarded. The method of making these determinations is in all cases identical. To force a stylet to move under the influence of the movement which it wished to inscribe is never a very difficult operation. This done, it suffices to receive the tracing on a surface which moves more or less quickly according to the movement which is intended to be inscribed. To measure the velocity of a projectile, a velocity of 200 to 300 *mètres* per minute is printed on the paper; whilst the growth of a plant should be inscribed on a paper which does not change its situation more than a few *centimètres* in the twenty-four hours.

In the enumeration just made, it may be noted that only very simple movements are treated of, moving in a rectilinear direction, sometimes in one direction only, sometimes alternately in two opposite directions. How, indeed, would it be possible to seize those capricious movements which arise in all directions of space? Though more complicated, however, my problem is not insoluble. Everyone is acquainted with the pantograph; everyone knows that, if the outlines of any given object be followed with one limb of this instrument, the other reproduces the same figure either reduced or enlarged. An analogous arrangement allows the inscription, at considerable distances, of all movements on the same plane. My apparatus is, like the two others described, composed of two parts, of which the one is the explorer and the other the receiver. These two parts transmit the movement to each other by air-tubes; each carries a point; and if one of them be led so as to trace a circle, you will see the other point likewise trace a circle; write your name with the first point, and your signature will be reproduced by the other instrument. An easily understood arrangement admits the reproduction of the movement according to its three dimensions in the space.

With these complex transmissions, there is no movement which cannot be reproduced. A flying bird, if of sufficient size, can carry instruments constructed on this principle; the creature, bound by one or two India-rubber tubes to the inscribing instruments, gives the curves of every movement it performs. Thus the trajectory of the wing at every moment of the flight is determined: the torsion movements which are imparted to it by the resistance of the air, even to the oscillations and to the jerks the body of the bird receives from the reaction of its wing-strokes.

I here terminate this exposition, which, though perhaps too long, is yet very much compressed. I have been able to show partly the results of a method which is yet in its infancy, and which, without doubt, will attain still greater perfection. Should we not, therefore, expect much from the graphic method? Should we not hope that, thanks to its employment, experimental science will advance with a sure and rapid step? Such is my profound conviction, and one which I should like to see widely shared.

CLINICAL LECTURE

ON A

CASE OF CYSTIC DISEASE OF THE LOWER JAW.

Delivered in University College Hospital.

By CHRISTOPHER HEATH, F.R.C.S.,
Holme Professor of Clinical Surgery.

GENTLEMEN,—The patient whom I bring before you, before sending her to Eastbourne, is the woman upon whom, a month ago, I performed an operation for cystic disease of the lower jaw. She was sent to me by Dr. Parsons of Dover, and was admitted on November 3rd, 1875, with the following history. About nine years ago, the patient first noticed a lump of the size of a pea beneath the tongue, on the right side, which gave her some pain, and for which a tooth was extracted. From that time, she had a succession of abscesses (?) in the lower jaw, some of which discharged in the mouth, and one externally, and for which she had several teeth extracted. Dr. Parsons sent her to me three years ago, and I then recommended her to come into the hospital; but she declined, and went on with a steadily increasing tumour of the lower jaw on the right side. About nine months ago, the tumour seems to have begun to increase with some rapidity, and, two months ago, the following characteristic event happened. While eating, the patient felt a sudden crack in the lower jaw, and this occurred twice in the same week; and upon each occasion she felt great pain in the floor of the mouth and upon moving the tongue. Upon admission, there was really very little to be seen externally, and I show you a photograph taken at the time to remind you of the fact that, excepting a very small projection beneath the skin in front of the angle of the jaw, there was nothing to call attention to the patient's face. On looking into the mouth, however, the tumour was at once obvious; and I show you a cast taken from the jaw at that time (Fig. 1). The right

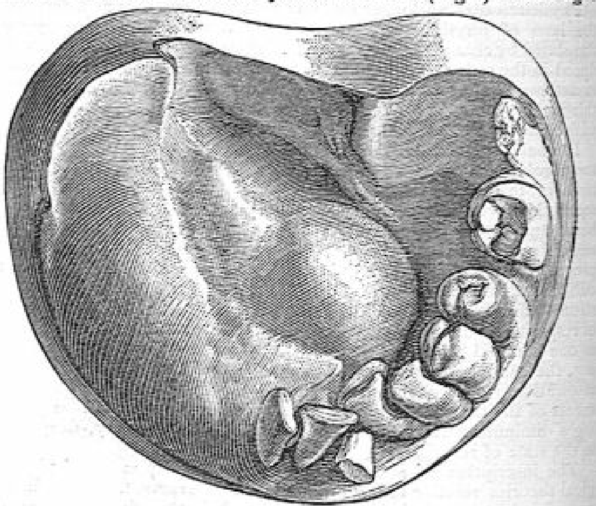

Fig. 1.

side of the lower jaw is seen to be greatly expanded from immediately in front of the ramus to beyond the median line, the tumour measuring two inches across at the broadest part, and reaching under the tongue. Its surface was lobulated and rounded, firm and osseous in the greater part, but yielding distinctly on pressure in two or three places. The mucous membrane was entire over the tumour, except at one point where there was an opening, from which a discharge constantly exuded. The incisor teeth of the right side were displaced over to the opposite side, and were loose. The central incisor of the left side was displaced completely in front of the other teeth. The left canine and