Dr Hughes Bennett
with the authors
Compts

ON THE

USE OF THE SPHYGMOGRAPH

IN THE

INVESTIGATION OF DISEASE.

BY

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ON THE USE OF THE SPHYGMOGRAPH IN THE INVESTIGATION OF DISEASE.

PART I.

The advances made of late in the diagnosis of disease by means of instrumental contrivances, have been so many and so great, that they will hereafter doubtless be considered as forming the chief characteristic of the Medicine of this age. The stethoscope has for years past been rendering our knowledge of certain diseases more exact, by enabling us to detect and follow changes in the condition of the thoracic viscera, that were, before its invention, hidden from us. The microscope has not only aided us in the diagnosis and prognosis of disease, but has wonderfully assisted in the elucidation of pathological change. Diseases of the eye, hitherto obscure, are now illuminated by the ophthalmoscope; and certain intracranial conditions promise to reveal themselves by the same means. The laryngoscope has thrown its light upon a region whose morbid conditions were before but vaguely understood, and has enabled us to treat locally the maladies of a tract into which, a few years back, it was doubted if an instrument could be passed.

The introduction of all these appliances has not only been followed by a much more perfect knowledge of disease, but has also preceded a no less considerable advance in its treatment. Any new aid, then, that ingenuity can devise to enable us to recognise with precision conditions that escape our unaided senses, we should gladly hail with no small hope that by its means we may be able to extend the limits of our knowledge.

To-night I have to bring before this society an instrument invented originally for physiological research, but which has since been applied to pathological investigation with no small advantage. Its inventor (M. Marey), impressed with the idea that a sound knowledge of the laws which preside over a function in health, must precede any improved knowledge of the disorders of that function, has first carefully investigated experimentally the physiology of the circulation of the blood, and then applied to its pathology the information thus obtained. (*Physiologie Médicale de la Circulation du Sang.* Par le Dr. E. J. Marey. Paris: 1863.) In such inquiry, the arterial pulse presented a prominence that could scarcely fail to attract much attention; and, to assist in its investigation, the sphygmograph has been invented, or rather modified.

The value of the indications afforded in disease by the pulse has been much neglected of late years, probably on account of the many and more accurate means at our disposal for obtaining information as to the state of the circulation. Our knowledge of its physiology also has not been sufficiently advanced, to render the attentive study of its morbid characters a fruitful subject; and, moreover, our means of appreciating its finer differences have been very imperfect. The finger placed on an artery perceives only the grosser peculiarities of the arterial movement, such as force, frequency, and regularity; the more subtle differences, in consequence of the fleeting character of the sensation experienced, escape our notice, or, when observed, convey no distinct or explicable idea to our minds. In order, therefore, that the pulse should yield valuable evidence in disease, we must first understand thoroughly its nature and causes; and secondly, we must so improve our means of investigating it, that we may recognise, and retain a knowledge of, its finer features.

The sensation of hardening and elevation felt by the finger placed over an artery, at each contraction of the heart, has been termed the arterial pulse. At each systole of the ventricle, we know that the blood driven into the arteries produces a varying amount of dilatation of the vessels. The arteries, distended by each new blood-wave, tend, by virtue of their elasticity, to contract upon their contents, and, while modifying by their recoil the ventricular force, they nevertheless drive the blood on its course. The greater the distension of the vessels, the stronger will be this elastic recoil, or, in other words, the arterial tension. The phenomena of the pulse are thus intimately connected with the tension of the arteries, and may be said to be "a direct result of the changes which the arterial tension experiences under cardiac action." Whenever we place the finger on an artery situated in a position favourable to compression (*e. g.*, over an osseous plane), the alternations of elevation and depression of the vessel tell us the variations in the tension of the arterial wall. The hardness of the pulse is, to some extent, a measure of the arterial tension; a softness, on the other hand, points to feeble pressure within the vessels. The movement of the blood through its channels gives, according to its character, many variations to the pulse form, which escape our unaided senses, and can only be collected and appreciated by an improved method of investigation.

The sphygmograph of Marey* affords us the necessary aid; and by it we can not only gain a knowledge of the finer differences which escape our touch, but also preserve for inspection a distinct trace of these delicate peculiarities. The accompanying woodcut (Fig. 1), copied from Marey, shews us in the interior of the frame (Q R) the essential part of the instrument, which consists of a flexible steel spring (I), covered on its under surface at its free extremity with a convex plate of ivory (K). This ivory plate rests upon the artery to be examined, and, by virtue of the elasticity of the spring (I), exerts a certain pressure upon it. Each pulsation of the vessel raises the spring slightly at K, and the multiplication of this movement is obtained by means of a very light lever (A), which moves upon a pivot (C). The elevation of the spring is transmitted to the lever, very near to its centre of movement, by means of a bar of metal (B E), which moves round the point (E); this bar terminates in a vertical plate (B D), and is pierced by a

* To the kindness of Dr. Anstie, I owe my first acquaintance with the instrument; and to him we are, I believe, indebted for its first introduction to a medical society in this country.

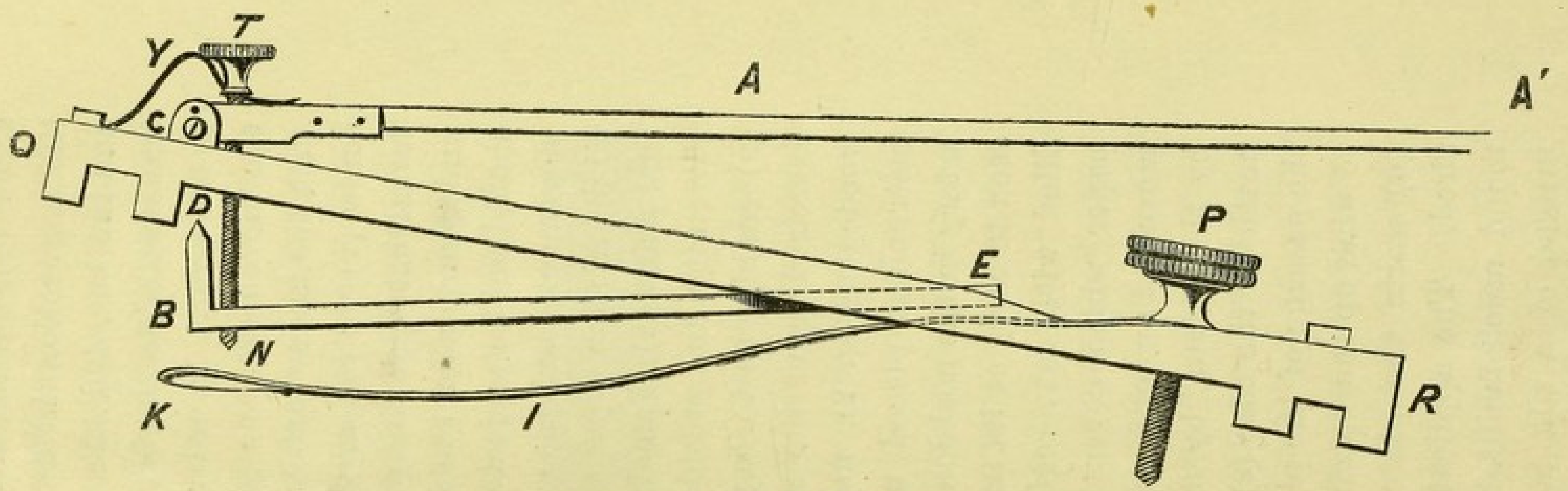

Fig. 1.—Marey's Sphygmograph.

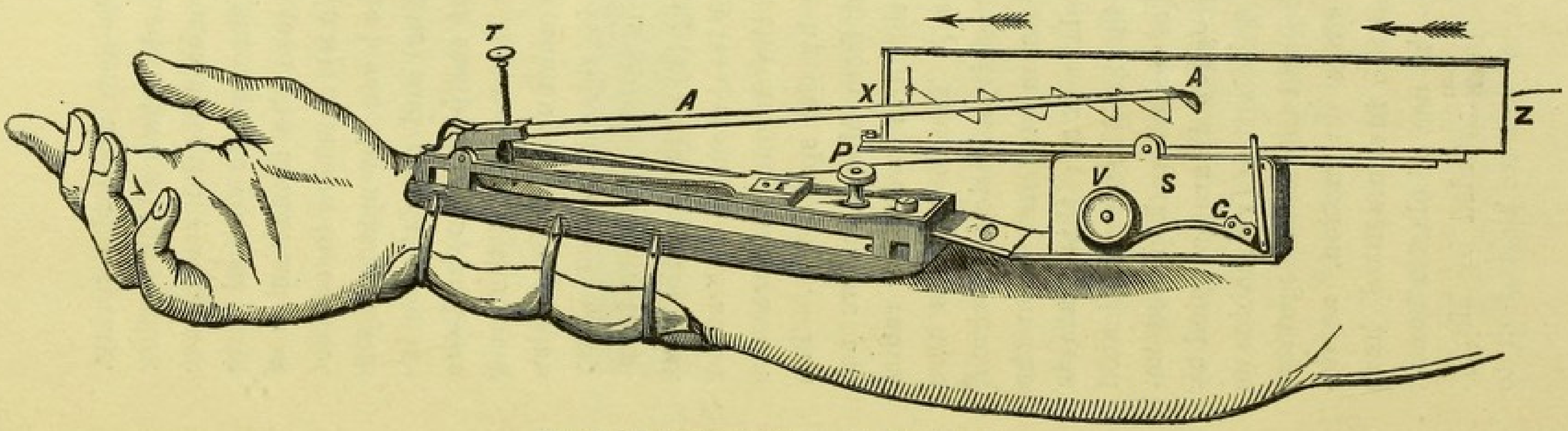

Fig. 2.—Sphygmograph applied to the Arm.

screw (T). When the screw acts upon the spring, the connection is established between the spring and the bar, and the movements of the spring are transmitted to the bar, and through its vertical plate to the lever. In order to insure the transmission of the movement, the plate (B N) must be in contact with the under surface of the lever; by means of the screw (T) we can arrange this, and regulate the interval between the point of the plate (B D) and the under surface of the lever. In order that the lever should not be projected too much upwards by sudden movement, and also that it should overcome any slight friction experienced in the paper at its terminal point (A), a small spring (Y) rests upon its fixed extremity, and presides over its descent. The screw (P) enables us to regulate the amount of pressure exercised upon the artery by the spring (I). The woodcut (Fig. 2), modified from Marey, shows the instrument placed upon the arm over the radial artery in the position for use. The lever (A) is here seen to carry at its free extremity a little pen, which, filled with ink, registers its movements upon the paper which covers the plate (X Z); this plate is moved at an uniform rate in the direction indicated by the arrows, by means of watch-work placed beneath in the case (S). Ten seconds are occupied by the passage of the plate. The button (V) enables us to wind up the watch-work; and the small regulator (G) starts the plate, or stops its motion, as desired. The application of the instrument I have found much facilitated by the use of elastic bands, instead of a silk lace, as recommended by Marey. These bands embrace the arm, and are hooked on to the small projecting points on the metal framework, as seen in the diagram. The addition of a pad* to the under surface of the arm renders the instrument more easy to the patient, and prevents any pressure from the bands.

The instrument, when in action, enables us to obtain an exact representation on paper of the pulse form; it also tells us the frequency of the pulsations and their regularity. It enables us, in addition, to see at a glance any peculiarity in the entire series, or in any single pulsation. A trace, as seen below (Fig. 3) is

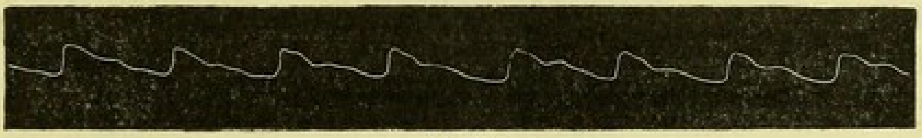

Fig. 3.

composed of a series of curves, each of which corresponds to a complete revolution of the heart, and is called a *pulsation*. Each pulsation is composed of three parts: the line of *ascent*, the *summit*, and the line of *descent*. The line of *ascent* is caused by the flow of blood into the arterial system after each cardiac systole; and tells us, by its form, the manner in which the blood enters the vessels. The more rapid the afflux, the more quickly the pressure in the arteries will be elevated, and the more vertical will be the ascent of the lever. When the entry of the blood is slow, the line of ascent will be traced by the lever obliquely, sometimes in a curved form. The line of ascent, in certain morbid conditions, exhibits a mixed form—the first part of the trace being vertical, the latter part curved. The

* I am indebted to my clinical clerk, Mr. Waters, for the suggestion of the pad.

summit of the pulsation corresponds to the duration of the arrival of blood in the artery, and designates the period during which the entrance balances the onward flow—in other words, the afflux and efflux are exactly equal. This period varies in length; it may be so short, that the summit becomes a mere mathematical point between the lines of ascent and descent, or it may be so long as to render the summit a horizontal line of some length. In the latter case, the lever traces the horizontal line, whilst the entry of blood into the vessel and its passage onwards mutually balance one another, and this line indicates the duration of the cardiac systole. The summit of the pulsation, when of any length, is not always horizontal; it may be formed by an ascending or descending plane, according as the afflux predominates over the onward flow, and *vice versâ.* In some cases a little hooked point may precede the summit; and this is a very valuable diagnostic element in the trace, as we shall see further on. The line of *descent* corresponds to the fall of the pressure in the arterial system, and is synchronous with the interval between the closure of the sigmoid valves and the next ventricular contraction. This line, by its obliquity, marks the celerity of the fall of the pressure within the vessels, and indicates the facility with which the blood passes on in its course. The frequency and amplitude of the pulse are pointed out by the obliquity of this line. The form may vary very much; sometimes it is purely oblique, at others a curve convex upwards, and occasionally one or more undulations may be seen in it. This last peculiarity is often very marked, and in some cases is perceptible to the finger; it has been termed *dicrotism.* By this term, we should only understand undulations occurring in the line of descent. Similar peculiarities have been pointed out in organic diseases of the heart; but in these cases the dicrotism belongs to the period of ascent, and is due to very different causes. The sphygmograph here gives us valuable aid; for it enables us to recognise in which period the peculiarity occurs.

Marey, from a series of remarkable experiments, concludes that this phenomenon is due to purely physical causes, and depends on the quickness of the entrance of the blood into the vessels and the elasticity of the arterial walls, whence results an oscillation of the column of liquid in a direction alternately centrifugal and centripetal.* The dicrotism will bear, then, a close relation to the rapidity of the ventricular contraction and to the elasticity of the arteries. Thus, in certain cases in which the blood enters the aorta slowly and the line of ascent is curved, the dicrotism is absent. When the heart contracts suddenly and forcibly, the blood enters the vessels with much speed, and then the rebounds are plainly seen.

The occurrence of dicrotism is favoured by whatever increases the elasticity of the arteries, and is opposed by whatever diminishes it. Thus, conditions

* Naumann has explained the dicrotism by the impact of the blood against the closed aortic valves, which, like the sudden stoppages of the flow through any set of tubes, produces a jarring impulse through the blood column. (*Vide* Carpenter's *Human Physiology*, 1864, p. 240.) I was inclined to prefer this explanation at one time to Marey's; but my observations on the occurrence of the dicrotism in certain diseases of the arteries and in cases of aortic insufficiency, have led me to accept the explanation given above.

which are associated with great elasticity of the arterial walls, as dilatation of the vessels and easy passage of blood through the capillaries, are marked by evident dicrotism in the line of descent. The trace (Fig. 4.) taken during the perspiration of hectic,

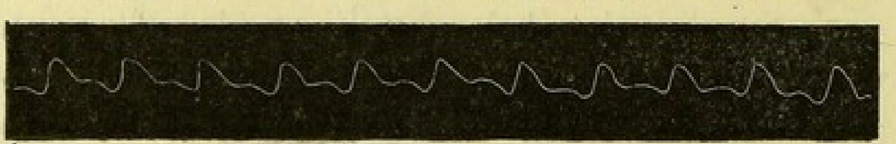

Fig. 4.

shows this characteristic. In the following trace (Fig. 5), the senile change in the vessels, and consequent loss of elasticity, is indicated by the absence of dicrotism—as well as by other characters to which we will hereafter refer.

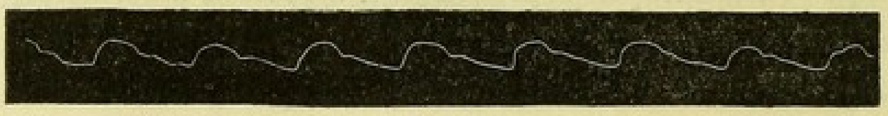

Fig. 5.

In examining a pulse-trace, one should note, in addition to the form of each pulsation, whether the summits of all of them can be joined by a straight line, and whether the bases can be also connected by a similar line parallel to the former. In some instances, this ceases to be the case, and a series of pulsations cannot be contained between such imaginary lines. The pulsations become irregular, and the line to join their summits or bases must cease to be horizontal.

The line joining the summits of a series of pulsations is the line of the maxima of *arterial tension*, and to it we will now confine ourselves. Its value as an indication is not absolute; it only tells us the variations that the arterial tension may undergo during the period of the observation; and it enables us to judge of the relative pressure within the vessels during any of the cardiac contractions registered. In the trace below (Fig. 6) by compressing the femoral artery during the first part of the trace, the tension was increased; and, on the compression being withdrawn during the latter half, the tension fell.

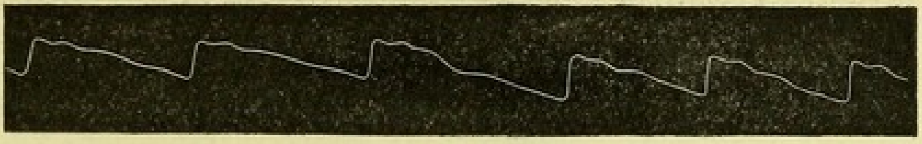

Fig. 6.

This line of greatest tension is of much value, and, with the corresponding line of least tension, should be observed in all cases, as these lines generally undergo parallel deviations, and a glance at either usually suffices to inform us of any change. Many influences act upon the pressure of the blood in the arteries; and of these, respiration is probably the most interesting, and will, when further investigated, yield much useful information to the physician.

The *frequency* of the pulse may be also studied by means of the sphygmograph; for, as the plate moves at an uniform rate and occupies exactly ten seconds in its passage, we can with ease calculate the pulse-rate. Slight variations in frequency, and irregularities, that would most probably escape the unaided touch, are by this means revealed to notice. The frequency of the heart's action, according to the French physiologist, depends very much upon the state of the circulation in the vessels of the periphery; an easy passage of blood favouring the increased action, a difficult passage, by reason of the greater arterial tension, causing diminished frequency of the ventricular systole.

The law is laid down, that, in the majority of cases, " the frequency of the pulse is in inverse proportion to the arterial tension." (Marey, *op. cit.*, p. 209.) M. Marey has made a series of experiments in reference to this point, and some of them I have been able myself to confirm. By the compression of any of the large arterial trunks, we can easily elevate the tension of the other vessels, and so diminish the frequency of the pulsations. This is seen in a trace already figured (6), in which the femoral was compressed. With the fall of arterial tension, on the removal of the compression, we can notice the increased frequency of the beats. In the trace below (Fig. 7) also, during

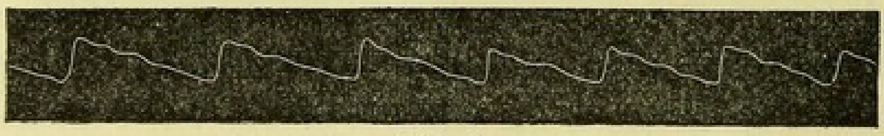

Fig. 7.

the first four pulsations, the arm and leg of the opposite side were elevated, and thus the arterial tension (as pointed out by Marey) increased; and, on the restoration of the limbs to the horizontal posture, during the remainder of the trace, increased frequency of the pulse, as registered, took place.

Of the following traces, the first (Fig. 8) was taken

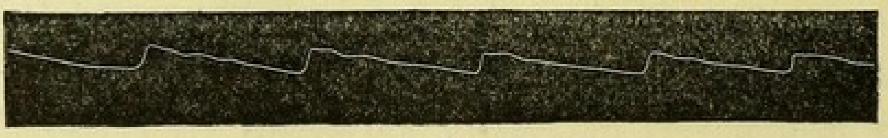

Fig. 8.

with the skin rather colder than usual; and the second (Fig. 9), twenty minutes afterwards, when, from increased warmth, the vessels on the surface were relaxed. A comparison of the pulsations of these traces points to the greater rapidity of the circulation under influences which facilitate the passage of the blood.

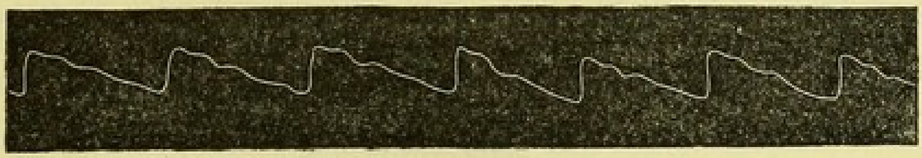

Fig. 9.

The *force* of the pulse is indicated by the height of the pulsations. The greater the elevation of the lever, the greater the energy of the pulse-beat; and we may say that, in many cases, the strength of the ventricular contraction is expressed by the force of the pulse. This law, however, has many exceptions; and we find that the altitude of the pulse-trace depends on several other conditions.

I. The volume of the artery greatly influences the amplitude of the trace. This can be well seen in traces collected from old persons. In senile changes, the volume of the vessels is increased considerably, and the trace betrays great fulness. Marey believes this to be due, not solely to the hypertrophy of the ventricle which exists in the old, but also to the dilatation of the artery. (*Vide* trace, Fig. 5.)

II. The state of arterial tension modifies greatly the force of the pulse; and, as the tension is dependent on the state of the capillary circulation, it may be said that in most cases "the force of the pulse is not in relation with the energy of the ventricular systole, but that it is regulated by the state of the circulation in the ultimate ramifications of the vascular system." (Marey, *op. cit.*, p. 235.) By means of the manometer, in a great number of experiments, this law has been proved to hold good; a feeble state of arterial tension giving to the finger and the instrument the sensation of increased amplitude. Marey, by means of the following diagrams (Figs. 10 and 11), illustrates this very well.

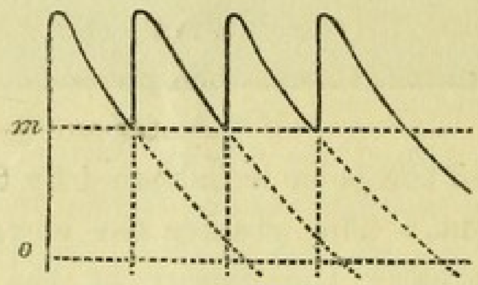

Fig. 10.

The first shows the form of pulsation in a state of feeble tension; the second, under a state of strong tension. The difference in the amplitude of the traces is very distinct. In the state of feeble tension, or easy passage of the blood onwards, the lever falls quickly to the point of least tension, and is ele-

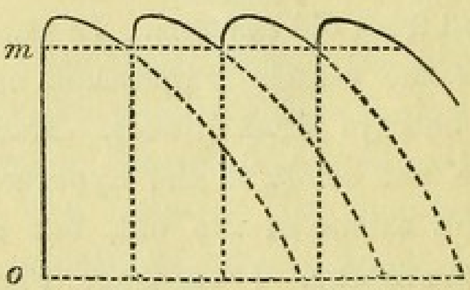

Fig. 11.

vated considerably at each pulsation. In the case of difficult passage of the blood through the capillaries, and consequently of great arterial tension, the lever descends slowly by a line convex upwards; and, long before it has reached a minimum tension equal to that in the former case, the lever is raised slightly by the next pulsation. While the lines of the maxima of arterial tension are the same in both cases, the lines of the minima are very different. On this depends the amplitude of the pulse-trace.

III. The duration of the interval which separates the pulsations has also a distinct influence on the amplitude of the trace. This is due to the fact that, during a long interval, the blood flowing continually onward lessens the pressure in the vessels, and thus favours the greater amplitude of the next pulsation. This is well seen in a trace (Fig. 12) taken from a patient of mine in the Queen's Hospital.

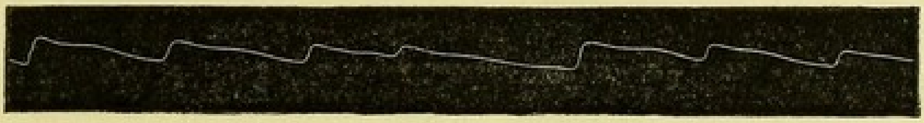

Fig. 12.

The condition of the vessel itself, as to permeability below the point observed, influences the force of the pulsation by altering the pressure within the artery. Marey has also pointed out that in some cases, where the pulse-beat is almost imperceptible to the finger, the sphygmograph records a considerable amplitude of trace; and *vice versâ*. I have been struck with this peculiarity in several instances; and the explanation appears to be, that we perceive changes in the artery more distinctly in proportion as they occur more suddenly. The cases in which the pulse has been almost imperceptible to the touch, but has nevertheless yielded a distinct trace, have been associated with a very slow distension of the vessels.

The foregoing remarks, based upon the work of the French author, will, I trust, by pointing out the meaning of the many forms of pulse-trace, and by setting before us the causes to which they are due, enable us to understand more clearly the changes exhibited by the arterial pulse-form in disease. The remainder of the paper I shall, with the permission of the Society, devote to a consideration of some few of the many pathological conditions in the detection of which the use of the sphygmograph renders us invaluable aid.

PART II.

Of late years, our knowledge of the pathology of the organs of the circulation has been much extended, and our power of detecting their morbid conditions has reached a point of much excellence; yet all will admit that there are many diseases of which we are even now but slightly informed, and many cases in which our power of diagnosing the exact cardiac lesion is often unsatisfactory. Many of these cases are examples of the early stages of maladies of which we know but too well the more developed phases. Many others are the slighter forms of organic change in which the functions are but little disturbed. By means of the sphygmograph of Marey we can detect changes in the movement of the blood that would ordinarily escape us; and by its use, I have no doubt we shall, when our observations have multiplied sufficiently, gain much information concerning morbid conditions in their earlier stages, as well as a knowledge of the slight indications capable of assisting in prognosis.

In the better understood diseases of the heart and great vessels, we can arrive at a diagnosis by the aid of the ordinary means employed; but in most cases the instrument of Marey can afford us useful confirmatory evidence, and in many it can perfect a diagnosis which percussion and auscultation have failed to complete. The pulse-trace alone often enables those skilled in its interpretation to foretel the sounds to be heard on auscultation; and in doubtful cases, by the information it yields, augments in no small degree the certainty of the diagnosis.

In the remainder of the time allotted to me, it will be my endeavour to point out a few of the morbid states of the organs of circulation, in which the pulse-form affords valuable indications. In doing so, I shall chiefly confine myself to diseased conditions of the organs of circulation, because I have had in such conditions the most extensive opportunities for investigation.

Among the pathological changes with which the arteries may be affected, is one that we so often meet with in old age, that we almost deem it the condition natural to our last days. I allude to that *Senile Change in the Vessels* which gives to the finger placed over the radial artery the sensation of resting on a hard inelastic tube. With such change in the arteries, we usually find hypertrophy of the left ventricle, and also a dilated state of the vessels themselves. We can easily account for these associated conditions, when we reflect that by such alteration the elasticity of the arterial walls is more or less destroyed. The special property, indeed, by which the arteries facilitate the onward flow of the blood and regulate its movement, is gradually lost; and the heart, thus deprived of one of its chief aids, is compelled to act more forcibly in order to carry on the circulation. Hypertrophy of the left ventricle is the consequence; and, little by little, the degenerated vessels, having lost their facility of modifying the force of the heart, dilate under the increased energy with which the blood is impelled into them.

Thanks to the luminous descriptions of Virchow, we are now well acquainted with forms of degenerative change other than ossification affecting the great arterial trunks; and we know also that such changes, as well as ossification, may occur at a comparatively early period of life. All these changes may extend over more or less of the vascular system; but they all have one common effect—they diminish the elasticity of the arterial wall.

This deterioration of a necessary property entails not only the changes to which I have above referred, but it is associated with an ever threatening tendency in the degenerated vessels to rupture under any abnormal pressure of the blood.

The power of detecting such alteration when it affects the larger trunks, leaving the superficial vessels healthy, would be a great boon to practical medicine, by enabling us to recognise with certainty a condition which we can now only vaguely surmise. The sphygmograph will assist us in this; for we find that certain forms of the pulse-trace are characteristic of senile degeneration of the vessels; and the appearance of these peculiarities in a minor degree in early life leads us to conclude that arterial change has occurred. The elasticity of the arteries transforms, as we know, the movement given to the blood by the ventricular systole; and, therefore, we find the least trace of the ventricular movement in the arteries most distant from the heart. But, whenever the arterial elasticity is diminished, the pulse retains more or less of the form given by the ventricular contraction.

M. Marey, by an ingenious experiment (*op. cit.*, p. 416), has obtained the trace of the ventricular systole (in a horse), which is figured below. In the diagram (Fig. 1), the dotted continuation indicates

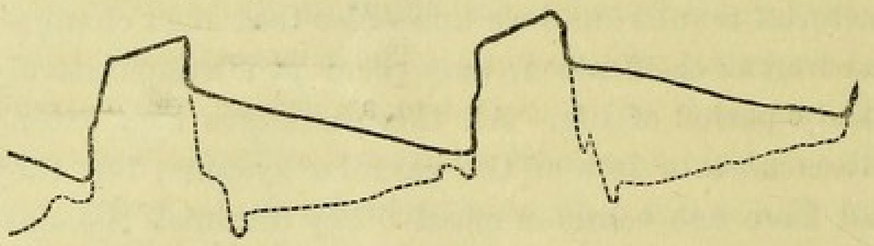

Fig. 1.

the traces of the ventricle, while the unbroken line shows the form which the arterial pulsation should possess in senile degeneration of the vessels. In the following traces, the resemblance to the ideal form is sufficiently striking. (Figs. 2, 3, 4.)

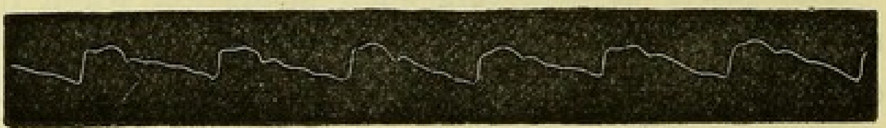

Fig. 2.

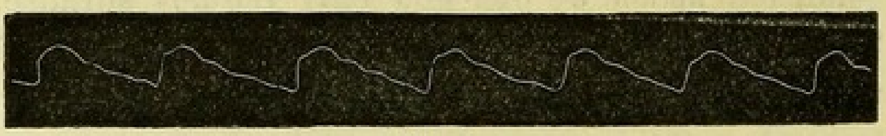

Fig. 3.

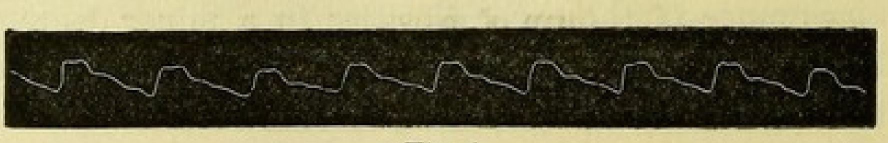

Fig. 4.

On examination, we recognise the following as the chief characters of the senile pulse : the great amplitude of the trace; the vertical and sometimes broken line of ascent; the extended summit; the sudden fall of the first part of the line of descent ; and its freedom from dicrotism.* These peculiarities are easily accounted for by the loss of elasticity in the vessels, the increased energy of the ventricle, and the dilatation of the arteries themselves. These features, when found in a minor degree in the pulse-trace of one little advanced in life, justify the opinion that there is arterial change. The rounded summit and the diminution of dicrotism are, when well marked, the first signs of alteration of the arterial elasticity. M. Marey has been able to test the diagnostic value of these characters by a *post mortem* examination. The pulse-trace (Fig. 5), taken by me in a case in

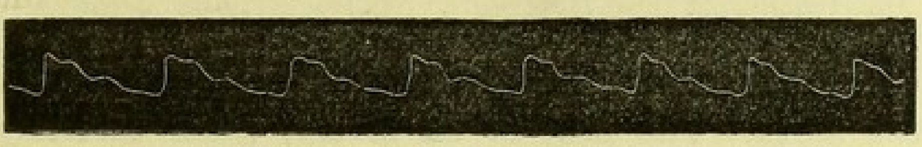

Fig. 5.

which considerable atheromatous change of the aorta and many of the larger vessels was found after death, shows the features of the trace of arterial degeneration in its more limited form. The trace (Fig. 6)

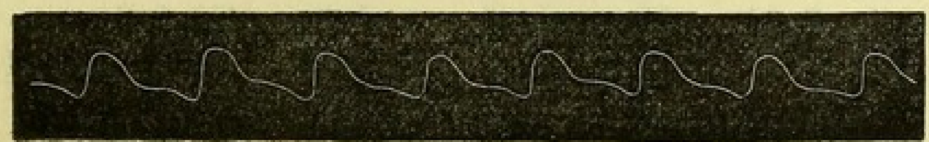

Fig. 6.

well shows the form of pulsation which excites suspicion of commencing arterial change. It was taken from a patient (age 37) in whom many symptoms lead to the diagnosis of this condition. The pulse-trace of

* I am indebted to the kindness of Dr. E. Robinson, Medical Officer of the Birmingham Workhouse, for the opportunity of obtaining the traces (Figs. 2, 3, 4) from inmates between 80 and 90 years of age.

strong tension simulates slightly that of senile change; but it is easy to discover if any of the causes of increased tension are acting.

In the investigation of *Aneurisms*, we shall find that the sphygmograph can afford us much valuable service, by showing us in the pulse-trace the modifications in the movement of the blood produced by the diseased condition.* These modifications are intimately dependent on the seat of the tumour, its size relatively to the vessel with which it is connected, and the elasticity of its walls.

We may, following the arrangement of the French author, consider, first, aneurism so situated on an artery that the pulse can be observed on the vessel below the tumour; and secondly, aneurisms affecting the aorta. The beat of an artery, when carefully felt below an aneurismal tumour which implicates it, is found to present unusual characters; it is weakened, and generally retarded. These changes are due chiefly to the fact that the blood has to traverse a sac whose elasticity much modifies the movement of the fluid, as Marey has proved by artificially producing the conditions in a series of experiments. By means of the sphygmograph, we obtain traces which point out that modifications of the pulse occur both in its form and force. In the pulse collected on an artery below an aneurism, we observe the changes which are the result of the transforming influence of the elasticity of the sac: the movement of the blood in the vessel approaches rather to that which is nor-

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* *Vide* (in *Lancet*, Jan. 20th, 1866) a case in which valuable information was gained from a consideration of pulse-traces by Drs. Sanderson and Anstie.

mally seen in the smaller arterial branches. The vertical line of ascent disappears; and often this line approaches in length that of descent. Thus we have a more feeble pulsation given to the finger; and, as the summit is slow to occur, there is further a sensation of apparent retardation felt in addition. In the following figures (7, 8) we see an example, in

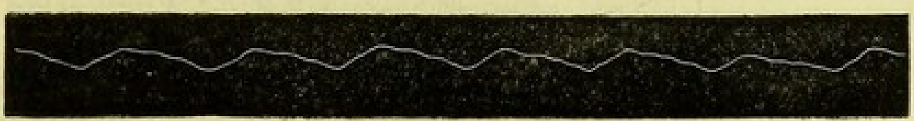

Fig. 7.—Left radial.

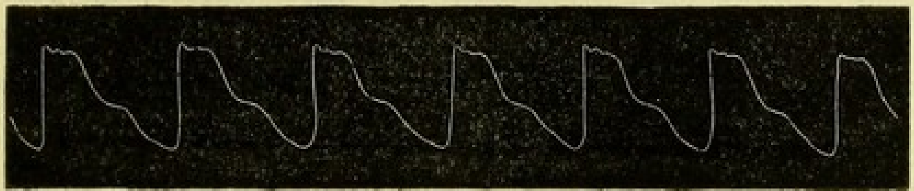

Fig. 8.—Right radial.

the pulse-trace of the left radial artery, of the modifying influence of an elastic aneurismal sac. The traces were taken from a patient in the Queen's Hospital (under the care of my colleague Dr. Fleming), affected with an aneurism of the left subclavian artery, within the thorax. The right pulse shows very well the trace of another lesion under which the man labours; viz., insufficiency of the aortic valves. So characteristic of the conditions in this case were the above traces, that they alone enabled me to arrive at the diagnosis, to which ordinary means had led those watching the case. At the time when the above traces were taken, the tumour was evidently large and very elastic: hence the great modifications in the pulse-form produced. I have, by the kindness of Dr. Fleming, had opportunities of examining this patient from time to time; and, since he has been under treatment, and has been kept strictly at rest, the traces taken below the aneurism now show much less modification in the pulse-form than formerly. (Fig. 9.) This we may attribute to

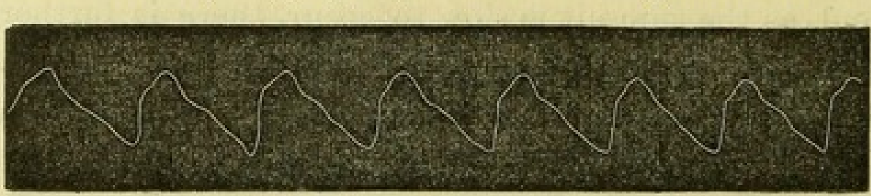

Fig. 9.—Left radial.

the diminution of the elasticity of the sac, following either deposition of fibrine on its interior, or the contraction of adhesions with neighbouring parts. In this case, the former supposition is rather warranted by the changes perceptible in the tumour.

In *Aneurisms of the Aorta*, we find that very much less striking indications are afforded by the pulse-trace. Those pointed out by Marey are: 1, modifications in the force of the pulse; 2, modifications in the intensity of the dicrotism; and 3, the existence of a constant difference in the pulse-form of the two radial arteries.

1. The force of the pulse, according to the French writer, is seldom much diminished. This character is only of small value in diagnosis. The causes of this want of change in force reside probably (*a*) in the small size of the tumour relatively to the volume of the aorta; (*b*) in the fact that the sac is sometimes not placed in the direct route of the blood, but communicates with the vessels, and thus has a much less transforming effect upon the blood-movement, than a tumour which must be traversed by the current; and (*c*) in the thickness and slight elasticity of the wall of the sac, often found in aneurisms in

this situation. The force of the pulse, too, in these cases is altered very often, not in one artery alone, but in the vessels of both sides of the body; and, on the other hand, it must be remembered that the tumour, by compressing the orifice of one of the branches of the aorta, may cause a peculiarity in the radial of one side.

2. The modification in the dicrotism may exist in one or both radial pulses, and is occasionally a sign of much value.

3. The presence of a constant dissimilarity in the pulse-traces of the radial arteries is the most valuable sign in the diagnosis of aortic aneurisms. In many cases, the finger can perceive a want of parallelism in the beats of the radials, but often this is too slight to be detected by the finger. It sometimes shews itself in the trace by a slight difference in the dicrotism only; at others, the difference in form is more evident. When the tumour is so situated that it can be handled, we can gain valuable evidence as to its nature by observing the changes in the tension of the arteries, produced by its alternate compression and relaxation. The traces (Figs. 10, 11, 12, 13) have been taken from patients suffering under intra-thoracic aneurisms; and the want of any great mo-

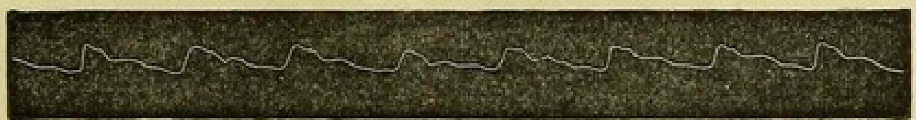

Fig. 10.—Left radial.

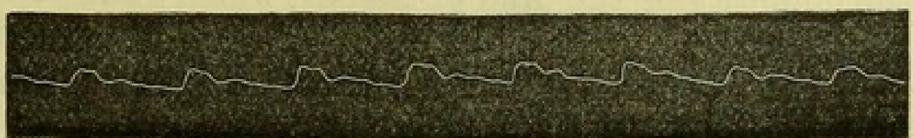

Fig. 11.—Right radial.

dification in the pulse-form of either radial has led me to consider the lesions as aortic.*

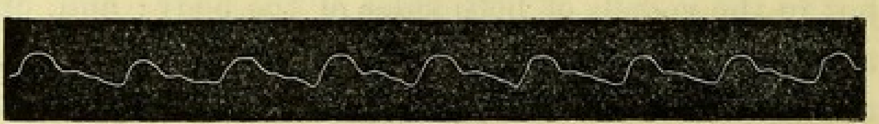

Fig. 12.—Right radial.

Fig. 13.—Left radial.

The detection of *Organic Diseases of the Heart* is rendered so certain by the use of auscultation and percussion, that we have but in few cases need of any other aid. In some cases, however, the pulse-evidence is useful; and this can be much more accurately and usefully obtained by the use of the sphygmograph than by any other means. I can now only briefly allude to certain affections of the cardiac orifices; and in these cases we shall find useful information yielded us by the instrument.

The changes of the aortic orifice to which I shall allude are those involving obstruction to the free exit of the blood from the ventricle, and those which allow of regurgitation. The first lesion is frequently met with, especially in the old, and produces often few symptoms, especially when it has gradually supervened, and the ventricle has had time to hypertrophy and counteract its effects. The pulse is generally regular; and the peculiarity observed in the trace is the obliquity of the line of ascent, which marks the

* I am indebted to Dr. Russell for an opportunity of seeing the patient from whom Figs. 10 and 11 were taken; and I have also to express my thanks to Drs. Casey and Steell for their kindness in assisting me in examining patients at the General Hospital.

greater duration of the ventricular systole and the gradual entry of the blood into the vessels. In the traces below (Figs. 14, 15), these characters are seen; but, as the second was taken from an old woman of

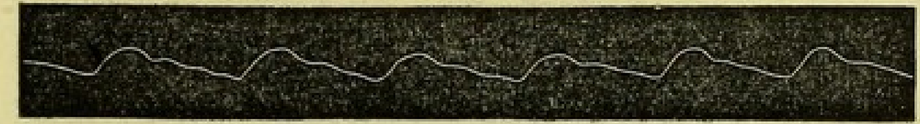

Fig. 14.

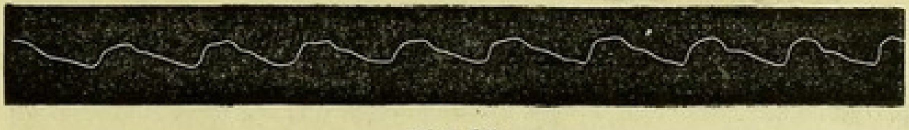

Fig. 15.

over eighty, the modifications of senile change are superadded.

Aortic insufficiency, or incompetency of the sigmoid valves, produces certain effects of a very striking character in the pulse-beat. These have been well described by Corrigan (to whom, indeed, our knowledge of the disease is chiefly due), and consist mainly in the jerking force of the pulse, its visible character, and the peculiar sensation given by it to the finger. These peculiarities are consequences of the regurgitation of the blood into the ventricle during its diastole. Marey has from his experiments concluded that the force of the pulse is not due altogether to the ventricular hypertrophy which accompanies the lesion, but that the amplitude of the trace and apparent force of the pulse are due really to the feeble tension of the arterial wall, which exists in consequence of the regurgitation during the ventricular diastole. In the first part of this paper, traces illustrating the effect of this feeble tension in increasing the amplitude of the pulsations have been figured. The traces (Figs. 16, 17), collected from patients suffering from aortic patency, are marked by the following peculiarities. There is great amplitude of trace, as just explained. The vertical line of ascent

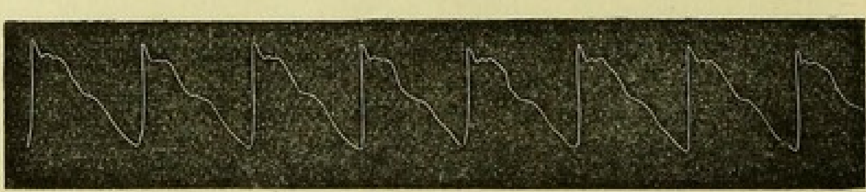

Fig. 16.

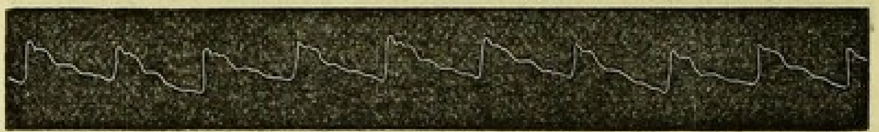

Fig. 17.

marks the sudden ventricular contraction; this vertical line is terminated by a sharp-pointed process, which indicates that, on account of its very sudden elevation, the lever has, by virtue of an acquired quickness, ceased to be connected for a brief interval with the arterial movements. The summit of the pulsation is in many cases very short; but in others it presents a horizontal or curved line, especially if any constriction of the aortic orifice, or other cause producing delay of the passage of the blood into the vessels, obtain.

The trace (Fig. 17) was taken in a case of aortic patency, complicated with senile change in the vessels.

In mitral insufficiency, the irregularity of the pulse so well known may be registered very accurately by the sphygmograph. This irregularity is its chief characteristic, and, when recorded, is very interesting.

In the traces below (Figs. 18, 19, 20), collected from cases of this disease, that numbered 20 was complicated with the signs of contraction of the auriculo-ventricular orifice. This additional lesion nearly

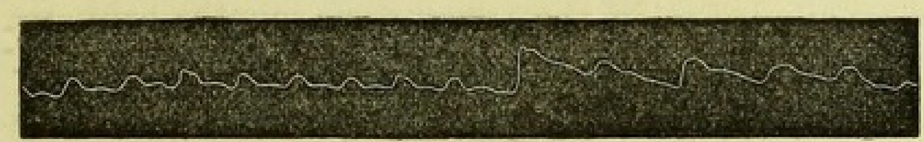

Fig. 18.

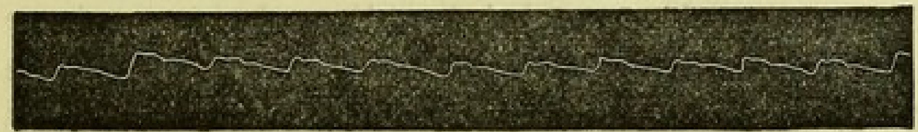

Fig. 19.

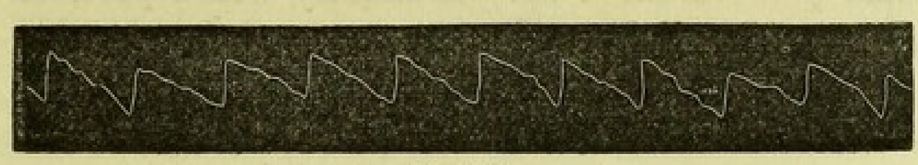

Fig. 20.

always diminishes the irregularity of the pulse-characteristic of pure mitral regurgitation.

In conclusion, I would call attention to the trace (Fig. 21) taken from a man suffering under lead-

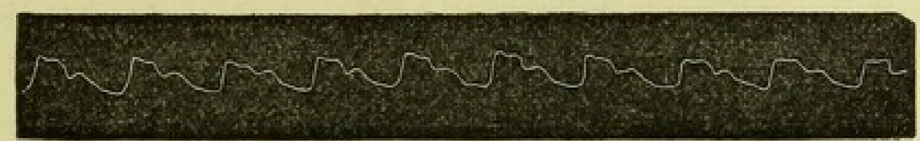

Fig. 21.

poisoning; it presents a peculiarity of form which has been figured by Marey, and which, when I saw it in his book, I scarcely expected to be able to verify so strikingly. I have since collected traces in several cases of this nature, and in all have met with this peculiar form. It may be indicated now as a curious fact: further investigation may discover the explanation of it. The subject of the pulse-form in acute disease, I may also add, is full of interest, and will, I am confident, from the little I have already seen of it, yield much interesting and useful information. This subject is receiving the attention of Dr. Anstie; and from his investigations, which were alluded to in the *Lancet* some months back, we have reason to expect some very valuable information. In now closing these remarks, I trust that this exposition of the views of the French physiologist have not only proved interesting, but may have also indicated a means by which we can render our knowledge of disease more accurate, and at the same time pointed out a field of inquiry which promises rich results to the investigator.

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