

**The sphygmograph : its history and use as an aid to diagnosis in ordinary practice / by R.E. Dudgeon.**

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Dudgeon, R. E. 1820-1904.  
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**Publication/Creation**

London : Baillière, Tindall, and Cox, 1882.

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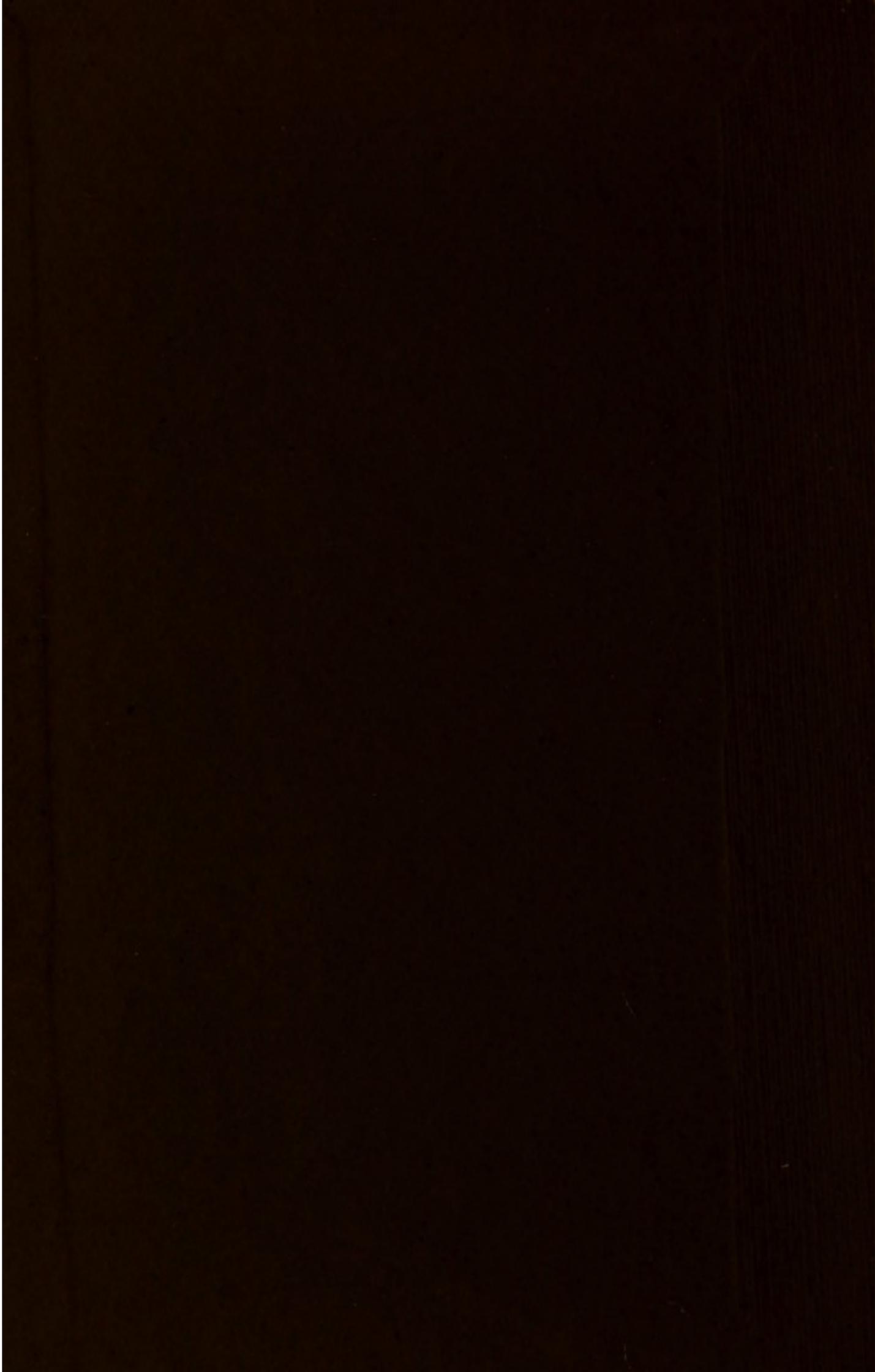
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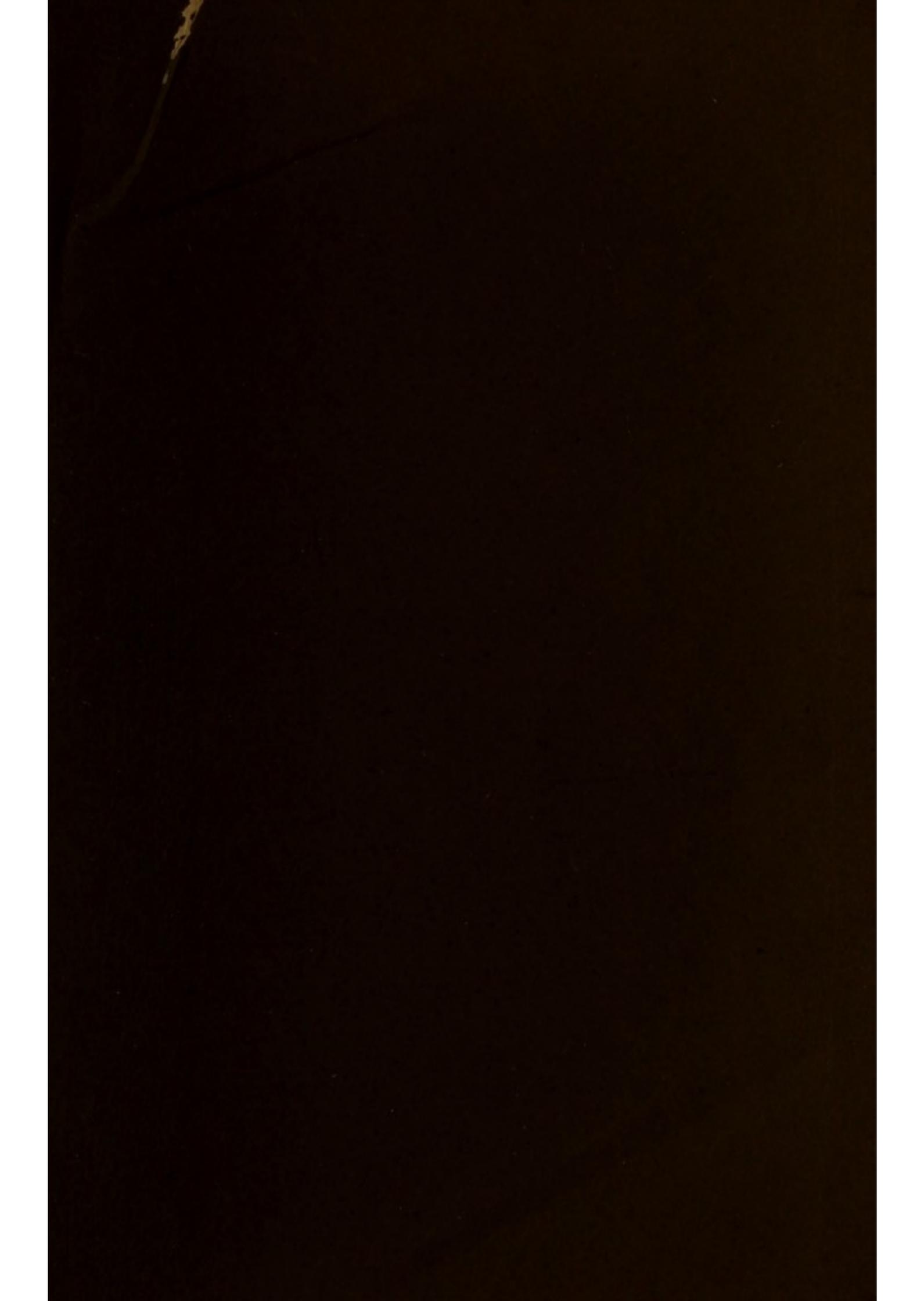
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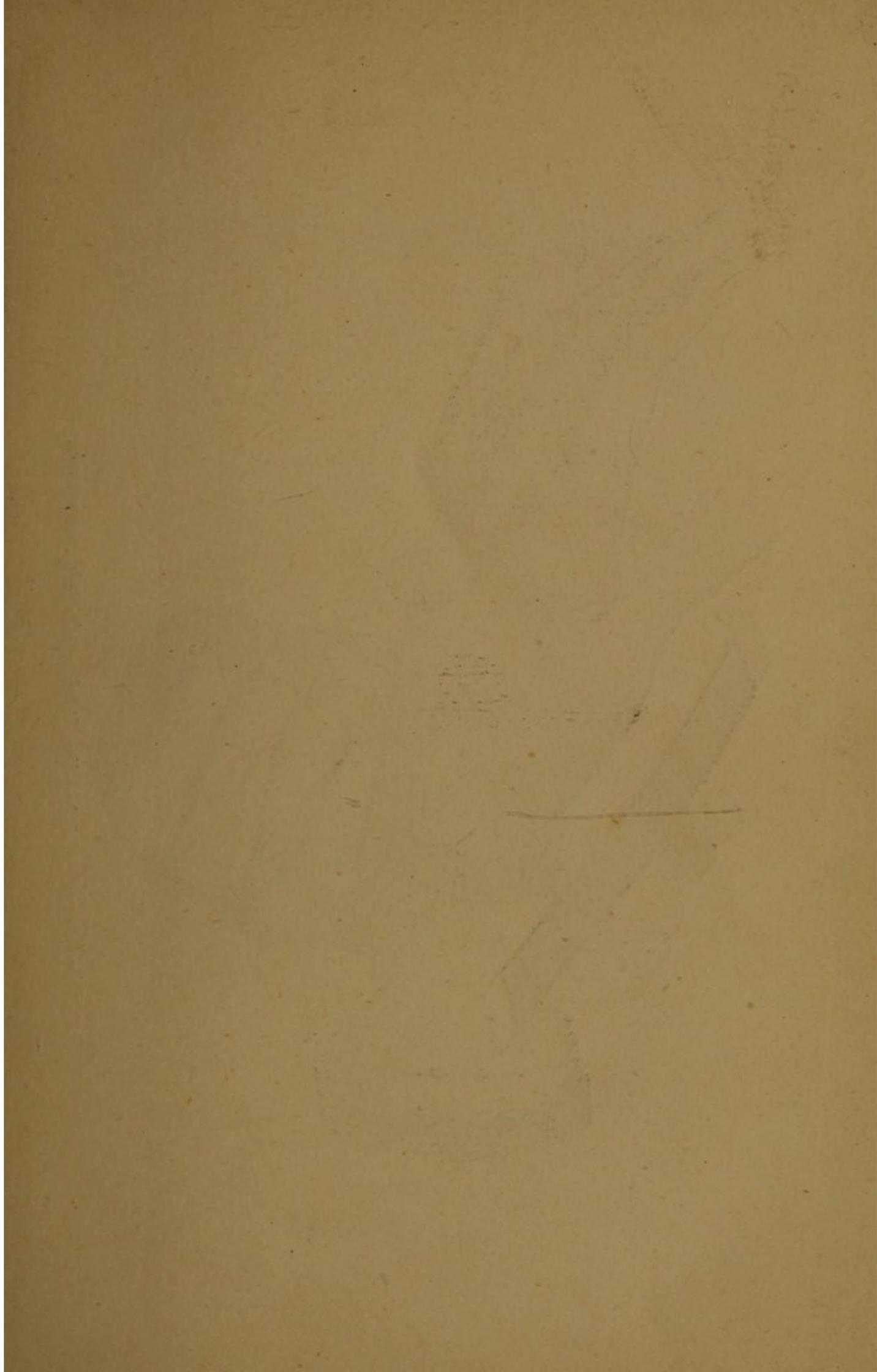
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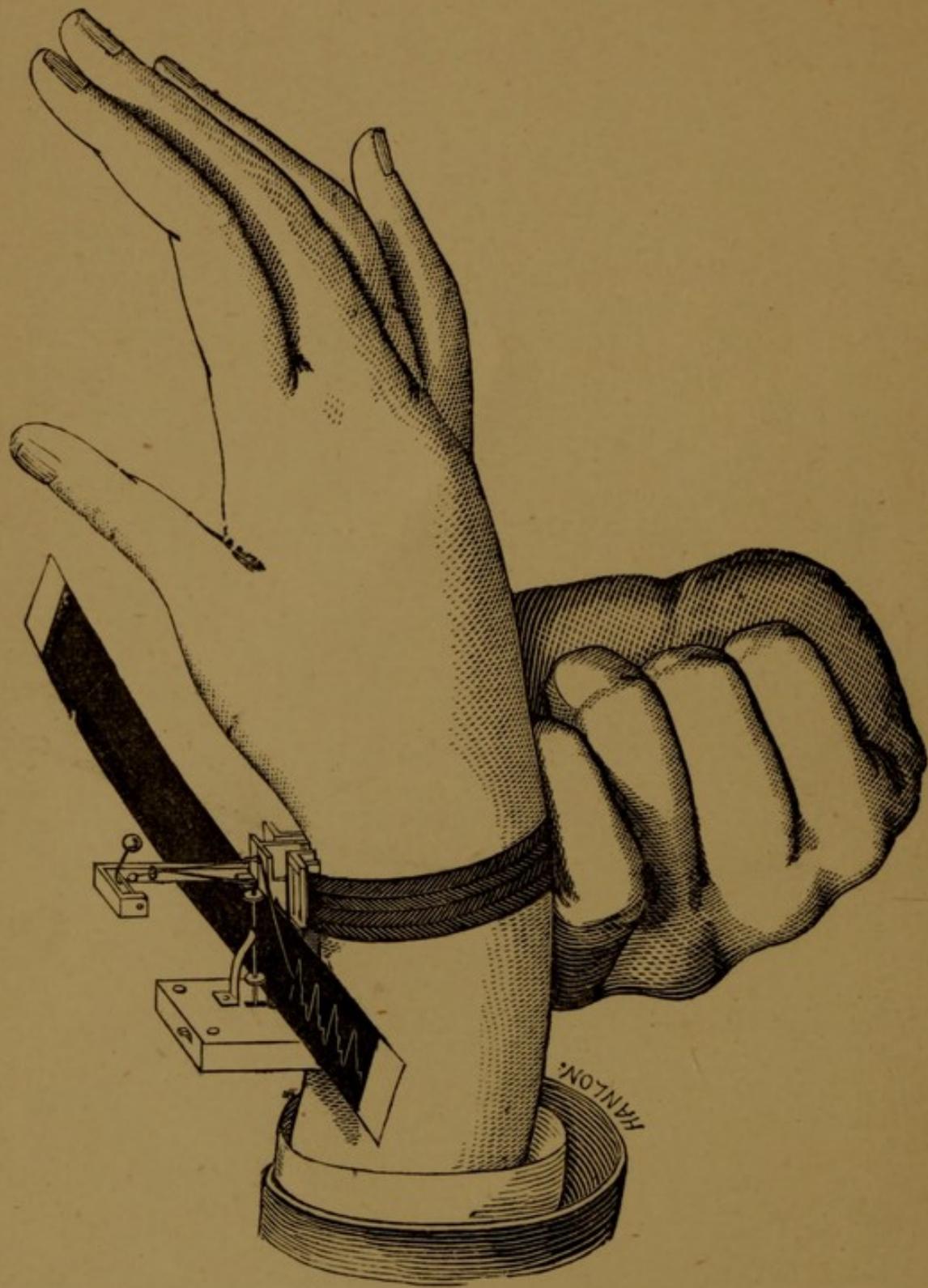
DODGEON





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Mode of applying Dr. Dudgeon's Sphygmograph.

THE  
SPHYGMOGRAPH:

*ITS HISTORY AND USE AS AN AID TO  
DIAGNOSIS IN ORDINARY PRACTICE.*

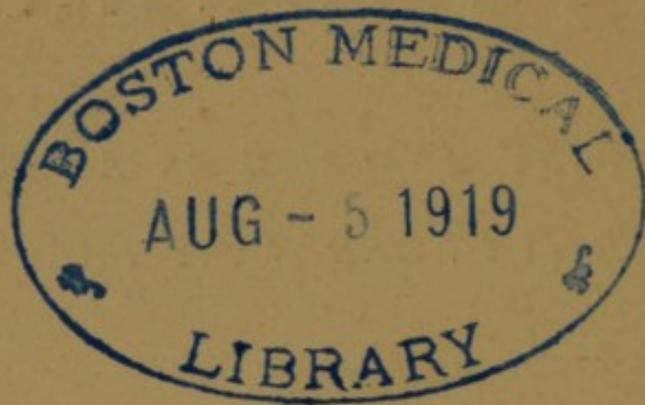
BY

R. E. DUDGEON, M.D.



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1882.

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## P R E F A C E.

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THE study of the pulse by means of graphic representations of the arterial movements has received a new impulse by the invention of a sphygmograph adapted for daily use in ordinary medical practice. I have frequently been asked to give some information for beginners on the subject of pulse-writing, and especially some fuller instruction on the use of the instrument I introduced to the notice of the medical profession some eighteen months ago, than are to be found in the printed directions given with the instrument.

In the following pages I have endeavoured to comply with this desire for further information. I do not intend in this little work to do more than its title implies: viz., to give a short account of the history of pulse-writing

and of the instruments invented for the purpose, and to indicate some of the uses of sphygmography in ordinary practice. I have also given full details respecting the principle and mode of employing my pocket sphygmograph, which obtained a first-class award at the International Medical and Sanitary Exhibition in 1881, and has received numerous commendatory notices from the medical press of this and other countries.

All the tracings given in the book were made with my instrument.

R. E. D.

MONTAGU SQUARE, LONDON.

*1st March, 1882.*



## THE SPHYGMOGRAPH.



SINCE the attention of physicians was first directed to arterial pulsations, some three centuries before our era, by the Alexandrian physician Herophilus—that robust vivisector\* who is said to have dissected alive six

\* 'Longeque optime fecisse Herophilum et Erasistratum, qui nocentes homines a regibus ex carcere acceptos, vivos inciderint,' says Celsus. From a vivisectionist point of view it is perhaps disappointing to think that the only physiological discovery Herophilus made, from all these hundreds of human vivisections, was that arteries pulsated, but he did not ascertain what the arteries contained; and that Erasistratus, his contemporary and rival human vivisector, announced as the result of his 'physiological experiments' on living men that the arteries contained vital spirits—an erroneous opinion that prevailed even down to Harvey's time, in spite of the convincing experiment of Galen, which proved that the arteries contained blood only. The contemplation of this infinitesimal outcome of these vast experiments, without anæsthetics, on living men should convince

hundred human beings, and whose name is gibbeted for ever at the place where four venous highways meet, known to anatomical students as the 'torcular Herophili'—through all the pre-scientific ages of medical practice, ere yet mechanical ingenuity had been pressed into the service of the art of diagnosis, much more importance was attached to the observation of the pulse than in recent times. Indeed, the physician of old made his diagnosis chiefly by observation of the pulse and tongue. But as the tongue could be rapidly inspected, and any one could judge of its foulness or cleanness as well as himself, he concentrated his attention mainly on the pulse, in the feeling of which there was always scope

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the anti-vivisectionists that they are unduly impatient when they object to the smallness of the results of the paltry experiments of modern physiologists on dogs, rabbits, frogs, rats, mice, and 'such small deer,' under chloroform. Every unprejudiced mind must allow that the discovery that human beings possess a pulse was cheaply purchased at the cost of six hundred human vivisections, for this discovery has been of incalculable use to the medical profession; though some cavillers might object that it might have been equally well made by applying the finger to the wrist; but then there are always unreasonable people to find fault with the methods of men of science.

for affecting the possession of peculiar skill and insight. To the uninitiated, who regarded the doctor as the depositary of occult knowledge, and who received his dicta as though they were oracles, there was something very imposing in his method of pulse-palpation. The fingers of the right hand daintily grasping the patient's wrist, while the doctor's eyes were riveted on the loud-ticking gold chronometer he held in his left hand, his head gravely nodding the while synchronously with the arterial pulsations—all this formed a picture calculated to inspire beholders with reverence and awe.

The pulse being the chief guide to diagnosis, its varieties of pace and strength were ascertained by the *tactus eruditus*, and carefully distinguished by special names. There was the *pulsus frequens* and the *pulsus rarus*, which by some subtle sense, lost to the moderns, were differentiated from the *pulsus celer* and *pulsus tardus*. There were, besides, the *pulsus magnus* and *pulsus parvus*, the *pulsus durus* and *pulsus mollis*, the *pulsus debilis*, *acutus*, *elatus*, *deficiens*, *celerrimus*,

*maximus*, *tremulus*, and other varieties, now forgotten. Our old physicians never quite attained the skill in pulse-feeling of which their Chinese colleagues boast, who pretend to distinguish upwards of three thousand varieties of pulses; but then the Celestials have been so much longer at the business than their occidental brethren, and have acquired such skill in the art that they are said to be able to diagnose every disease by the pulse alone, whereas European doctors have always considered it necessary to supplement the knowledge conveyed by the pulse by other sources of information.

When instrumental aids to diagnosis began to be introduced by the inventions of the stethoscope and pleximeter, the various specula, the microscope, and the other 'scopes and 'meters that now form the everyday armamentarium of the physician, the art of pulse-feeling was neglected or performed in a perfunctory manner, and its importance was regarded as a very secondary affair.

But the pulse could not for ever remain beyond the reach of instrumental investiga-

tion, and when almost every other function of the body was supplied with some ingenious instrument for its elucidation, the attention of inventors was directed to the discovery of some means for sensibly displaying the variations of the pulse in health and disease.

The idea of rendering visible the movements of the blood in the arteries actually originated in the pre-instrumental age, and the pioneer of sphygmography was not a physician but a clergyman. The Rev. Stephen Hales\* was the first to devise a method of demonstrating the force and movements of the pulse. He inserted a glass tube one-sixth of an inch bore, and nine feet long, into the femoral artery of a horse. He noted the height to which the blood rose in this tube held perpendicularly, and the movements that occurred with every pulsation. He then drew off a quart of blood, and observed the diminished height of the column of blood. He

\* *Statical Essays*, vol. ii., containing *Hæmostatics, or an Account of some Hydraulick and Hydrostatical Experiments made on the Blood and Bloodvessels of Animals*, by STEPHEN HALES, B.D., F.R.S., Rector of Farringdon, Hampshire, and Minister of Teddington, Middlesex. London, 1733.

continued his observations after abstracting successive quarts of blood until the animal died. He performed similar experiments on deer, sheep, and dogs, and made careful records of the varying height of the column of blood whilst the animals were slowly bled to death. His experiments were made not so much for observing the movements of the blood in pulsation, as the height to which the column of blood rose in the tube, from which he calculated the force of the heart. The reverend experimenter combined the two occupations of clergyman and vivisector, which would be thought rather incongruous nowadays. He called his instrument a *puls-manometer*.

Whether owing to the pride of the medical faculty, who would naturally scorn to be instructed in physiology by a parson, or because the method pursued by Hales did not appear to give promise of any important addition to physiological knowledge, the experiments of the reverend vivisector remained unnoticed and neglected for near a hundred years, until they were unearthed by a young

candidate for a medical degree in Paris, M. Poiseuille,\* who varied Hales's method of procedure by employing a bent glass tube partially filled with mercury. One end of this tube was inserted into the artery, and the blood injected into the tube by the arterial pulsations caused the mercury to rise in the farther limb of the bent tube. The height to which the mercury rose at each pulsation was noted on a scale, and the force of the heart calculated thereby. He called his instrument a *hæmodynameter*.

Vierordt† went back to Hales's original plan of the long tube, which he filled to the height of five or six feet with a solution of carbonate of soda. This had the twofold advantage of sparing the expenditure of blood and retaining the blood that entered the tube in a fluid state.

An instrument on a similar principle is described by Setschenow.‡

\* *Recherches sur la Force du Cœur aortique*, par J. M. POISEUILLE; thèse. Paris, 1828.

† *Die Lehre vom Arterienpuls*, von KARL VIERORDT. Braunschweig, 1855.

*Zeit. f. rat. Med.*, xii. p. 334, 1861.

Fick\* inserted a tube into the artery. This tube was filled with a solution of carbonate of soda; it was connected with an elliptical tubular brass spring, bent in the form of the letter C, which tended to straighten itself when it received the impulse of the arterial pulsations. The slight movements thus manifested at its free end were magnified by a lever which made a tracing on a smoked revolving drum. The tracing consisted of simple up-and-down strokes. He called his invention a *Blutwellenzeichner*. A figure of it will be found in CARPENTER'S *Physiology*, eighth edition, p. 342.

Ludwig† employed Poiseuille's bent tube and mercurial column. He put a float on the top of the mercury, whence rose a stem, to the top of which a needle was attached, which traced the movements communicated to it by the fluctuations of the mercurial column on a strip of paper stretched on a revolving drum.

\* *Archiv für Anat., Phys., etc.*, von REICHERT und DU BOIS RAYMOND, 1864.

† *Die physiologischen Leistungen des Blutdrucks*, von CARL LUDWIG. Leipzig, 1865.

These tracings were mere up-and-down strokes, very unlike the sphygmograms we are now familiar with. His instrument was called a *kymographion*.

Experiments with these instruments were necessarily confined to the lower animals, as they could not be used without opening an artery, an operation which would not have been willingly submitted to by any human being or other animal who had a choice in the matter.

Herisson\* modified the instrument by employing a straight glass tube, closed at the lower end by an elastic membrane, and partially filled with mercury. This could be applied without injury to the artery, and the movements of the bloodvessel were transmitted through the membrane to the mercurial column, which moved up and down in the tube. Its inventor called it a *sphygmometer*.

Scott-Alison† constructed a *sphyngoscope*

\* *The Sphygmometer, an Instrument which renders the Action of the Arteries apparent to the Eye*, by DR. JULIUS HERISSON, with an *Improvement of the Instrument and Preliminary Remarks*, by DR. E. S. BLUNDELL. London, Longmans, 1835.

† *Philosophical Magazine*, Fourth Series, xii. 1838.

on a similar principle. One form of it was used for application to the chest for cardiac observations, another for application to the radial artery. He used spirits of wine in place of mercury in the tube.

O. Naumann\* modified Herisson's instrument by filling the tube with mercury and attaching to its free end a small tube of india-rubber from the distal end of which a long style depended. The movements of the artery communicated to the column of mercury tended to straighten the india-rubber tube, and hence to move the depending style, which traced the movements on a revolving drum.

Herisson's principle has been adopted by Mr. Butcher of Reading, in his ingenious little *sphygmoscope*, where a coloured fluid is inclosed in a glass tube, the end of which is closed by an india-rubber membrane. This is applied to the artery, the movements of which are communicated to the coloured fluid. The instrument may be used in both a vertical and a horizontal position.

A similar instrument is figured and de-

\* *Zeitschrift für rat. Med.* xviii. 1863.

scribed in a recent number of the *American Medical Record*. The author's name has escaped me, but the instrument resembles that of Herisson as modified by Blundell.

Vierordt\* seems to be the first who constructed a *sphygmograph* where the movements of the artery were communicated to a lever which recorded these movements graphically. The lever was provided with a cup for the reception of weights for regulating the pressure of its stud upon the artery. The tracings he made with this instrument are simple up-and-down strokes. He tells us that if overweighted the tracings become of an irregular character, the down-stroke having several little curves upon it; but this he considers should be avoided, and the weight reduced so that the simple up-and-down strokes only should appear. What he calls 'incorrect tracings,' of which he gives some examples, are, in fact, similar to those obtained by an ordinary sphygmograph. Thus he took great pains to furnish us with a meaningless tracing.

Longuet† describes a sphygmograph of his

\* *Op. cit.* † *Bull. de l'Acad. de Médecine*, xxxiii. p. 962.

invention, where a pad placed on the radial artery acts on an upright piece like a fiddle-bow, the string of which passes over a small wheel, which in its turn moves a larger disc, on the edge of which is a pencil that, as the wheel moves, makes a magnified representation of the arterial movements on a strip of paper moved by clockwork. This apparatus being all in the air, must be difficult of application and deficient in stability.

L. Waldenburg\* invented a *pulse-clock*, a complex machine which registers the movements of the artery on a dial, in appearance something like a clock-barometer. It does not give a graphic tracing of the pulse.

Marey's† *sphygmograph* consists of a long spring furnished with a pelotte or button, which is fastened over the radial artery. The movements of the spring are communicated to a long lever, furnished with a style or pen that traces the movements communicated to it

\* *Die Messung des Pulses und des Blutdrucks.* Berlin, 1880.

† *La Méthode graphique dans les Sciences expérimentales,* par ETIENNE JULES MAREY. Paris, 1878.

on a strip of smoked paper or glass, moved by clockwork. This apparatus extends longitudinally up the arm, and is difficult of application, as it requires a complicated arrangement of straps and a double-inclined arm-rest. It is altogether so cumbrous that it is unfit for use in general practice. This instrument, with its modifications by Burdon Sanderson\* and Mahomed,† has hitherto been the one most generally used in this country. When properly applied it makes a tolerably good tracing; but the end of the lever being fixed, the up-stroke of the tracing describes a segment of a circle backwards, which gives an erroneous idea of the systolic impulse. Its size and formidable appearance are apt to alarm the patient. Dr. Byrom Bramwell‡ tells us that one of his patients left the hospital rather than have the instrument applied.

Some months since the medical periodicals announced that Marey had constructed a small

\* *Handbook of the Sphygmograph.* London, 1867.

† *Medical Times and Gazette*, 1872.

‡ *The Examination of the Pulse.* *Edin. Med. Journ*  
Dec. 1880

sphygmograph that could be carried in the waistcoat-pocket, which took tracings of the pulse of such minute size that they had to be viewed through a microscope in order to make them out distinctly. I have not seen this instrument, and do not know if it is used in practice.

Baker\* describes what he calls a simplification of Marey's sphygmograph. It consists of a wooden plate eight inches long, that is laid on the forearm. It is perforated by a hole where it lies over the radial artery. Through this hole a pad of ivory, covered with cork, presses on the artery, and is adjusted by means of a screw turned by a milled head; this pad acts on a long lever of steel or aluminium, which extends up the arm. Its free end contains a small copper ink reservoir, from which projects a fine hair pencil. This pencil makes a tracing of the movements communicated to the lever on a long strip of paper, which is wound round a drum. A clockwork apparatus unwinds this strip of

\* *A New Form of Sphygmograph. Brit. Med. Journ* 1867.

paper, which passes between two other drums. Any length of paper up to six feet may be used. The whole instrument is fastened securely to the arm by straps. The alleged simplicity of this instrument does not seem to have been appreciated by the profession, as it has not superseded the more complicated instrument of Marey.

Mach\* modified Marey's invention by attaching to the end of the spring above the stud a perpendicular toothed stem, which moved a toothed wheel fixed to the writing-lever. In this way he thought he got rid of all spontaneous movements or oscillations of the writing-lever.

Landois† describes an instrument of his own invention which he calls an *angiograph*. It consists of two double levers, one above the other, both having a counterpoise on their shorter arm. Near the free end of the lower lever a stem descends, ending in a stud that

\* *Sitzungsberichte der K.K. Acad. der Wissensch. zu Wien.* 1863.

† *Die Lehre vom Arterienpuls*, von LEONARD LANDOIS, Berlin, 1872, p. 70.

receives the impulses of the artery. At the extremity of this lever there rises a toothed stem that plays upon a toothed wheel, fixed on the hinge of the upper lever. Every movement of the lower lever is communicated to the upper lever, at the free end of which is a loosely-hanging curved needle that makes a tracing on a smoked paper travelling at right angles to the arm and inclined obliquely to the needle. By this arrangement Landois gets rid of any spontaneous movement of the writing-lever, and the up-strokes of the tracing are perpendicular in place of being curved as in Marey's instrument and its modifications.

Sommerbrodt's\* *sphygmograph* is an extremely complicated modification of Marey's. When applied it extends as high as the elbow. The frame that supports the tracing-paper, with its driving clockwork machinery, is arranged transversely across the arm, and is propped up by two crutches that rest on the table on which the arm is laid. The needle at the end of the long lever makes a tracing on the reverse side of the paper. The tracings

† *Ein neuer Sphygmograph.* Berlin, 1876.

of the pulse given by the author seem to be very poorly defined, and, unlike those of other sphygmographs, run from left to right.

Berti's\* *sphygmometer* is a bracelet of india-rubber or silk, which carries a graduated disc, on which a pointer runs or oscillates. On the inside of the bracelet is an elliptic concave shield, which fits on to the radial artery, and transmits its movements by means of a multiplying lever to the pointer. This shield he calls *il raccoglitore*. The arm must be in the supine position, the hand stretched out as much as possible. No graphic tracing of the arterial movements is made.

In Pond's *sphygmograph* the pulsations of the artery are communicated to an india-rubber cap tightly stretched over an oval metallic ring. The movements of the india-rubber disc are conveyed to a piston, which moves a perpendicular metallic stem, and thence to an oblique rod, which has a counterpoise at its lower end and a needle at its upper end, which traces the movements communi-

\* SCHMIDT'S *Jahrbücher*, vol. c. p. 55; from *Gaz. Lombard.* 1857, No. 18.

cated to it on a smoked paper, propelled below it by a clockwork apparatus contained in a metallic box. The chief objections to this instrument are that the spring on which the pulse acts being of india-rubber, its pressure on the artery cannot be altered. Moreover the base on which the india-rubber is stretched being a complete oval ring of hard metal, presses on the artery above and below, and hence must interfere with the movements of the artery. The instrument is besides top-heavy, as the clockwork is supported by a stout metallic stem several inches above the wrist. A wrist-rest, with arms and screws for fixing the upright stem, is provided, though the instrument may also be used without this wrist-rest. The original instrument had a graduated slide to indicate the pressure, but as it only indicated the pressure of the oval metallic ring on the wrist, and not that of the india-rubber on the artery, its misleading character seems to have been recognised by its inventor, and the later instruments are made without this graduated slide.

The instruments constructed on Marey's

plan—at least the modifications by Sanderson and Mahomed—profess to regulate and indicate the pressure of the spring on the artery, but none of the sphygmographs hitherto in use, as far as I am aware, indicate the degree in which the movements of the artery are magnified.

Other methods of giving a sensible rendering of the arterial movements have been invented. Thus Stein\* describes a *photosphygmograph*. Its principal parts are: a brass frame, which is fastened by straps to the wrist; in the centre of the frame is a spring fixed to the frame at one end, the other end being free and provided with a stud which receives the movements of the radial artery and communicates them to an upright stem, on which is a blackened mica-plate pierced with a small hole, through which a small ray of sunlight is transmitted to a strip of sensitised paper, which is driven along by clockwork, and thus a photographic tracing is made. The movements of the artery being unmagnified, make but a small tracing; but by adapting a long

\* *Die Lichtbildkunst*. Stuttgart, 1877.

lever to the upright, and placing the perforated mica-plate on its free end, the tracing can be magnified to any desired extent. The chief objection to this instrument is its want of simplicity, and the impossibility of using it unless one can command the light of the sun, or in its absence an electric light. Czermak\* also constructed a photosphygmograph somewhat on the same principle, only the ray of light is reflected from a small mirror in connection with the lever of the sphygmograph, and thrown on a screen of sensitised collodion.

The movements of the artery have been rendered audible by instruments called *sphygmophones*. One, the invention of Dr. Stein, consists of a spring fastened on the artery as in the last-named instrument. The free end of the spring, provided with a stud to be placed over the artery, communicates its movements to a metal point that connects and disconnects itself with a metal point placed above it, which again is in communication with the wire of a telephone. When a galvanic current is passed

\* *Mittheilungen a. d. Privat-Laboratorium*, H. i. 1864.

through the apparatus the crackling sound accompanying the connection and disconnection of the two metal points is distinctly heard.

Dr. B. W. Richardson takes a sphygmograph and causes the needle to move upon a microphone which is connected with a telephone, and a variety of sounds is heard according to the character of the pulse under examination. Both these instruments require a galvanic battery, which is necessarily not very portable; hence their use in ordinary practice is scarcely to be thought of; nor do the results seem to me to be of much practical use.

Another method of exhibiting the arterial movements is that of Chelius\* of Holzappel (who also describes a *Pulsmesser* very similar to that of Herisson). His *Kastenpulsmesser* is a box which encloses a whole limb. This is filled with water, and a tube rising up from it allows the water to rise and fall in it synchronously with the pulsation of the arteries in the limb. With this instrument he succeeded in first establishing the dicrotism of the pulse. Poseuille carried out a similar idea in his *box-*

\* *Prager Vierteljahrschrift*, 1850.

*pulsometer*, but he only included a portion of an artery in a very small box, likewise filled with water and provided with a tube in which the water rose and fell as the enclosed artery pulsated.

The graphic method is the only one of real practical utility for observations on the pulse. Hence sphygmoscopes and sphygmophones may be regarded as ingenious toys, but the sphygmograph is the only instrument that can be recommended for determining accurately and permanently the true character of the pulse.

A sphygmograph to be of use in daily practice, should possess the following qualities: 1. It should be small so as to be easily carried in the pocket. 2. It should be capable of being used easily and quickly. 3. It should not require the cumbrous accessories of wrist-rests. 4. It should be applicable to the wrist without requiring the arm to be bared up to the elbow. 5. It should be capable of being used in any position of the patient, whether standing, sitting or lying. 6. It should magnify the movements of the artery in an accurately

ascertained degree. 7. The pressure of the spring upon the artery should be capable of being increased or diminished at pleasure while the instrument is *in situ*. 8. The paper on which the sphygmogram is traced should move through the instrument at a uniform and ascertained rate. 9. The various parts of the instrument should contribute to its stability on the wrist. 10. The levers to which the tracing needle is attached should play freely and unconstrainedly, and not be rigidly attached to the unyielding frame of the instrument, in order to allow it to respond quickly to the movements communicated to it by the spring that receives the arterial pulsations. 11. The tracing made by the needle should be clear and sharp, displaying all the little secondary wavelets that accompany the play of a lively pulse.

The instrument I introduced to the notice of my colleagues in 1880 possesses all the above requisites. The wood-cut (Fig. 1) gives its actual size, which is two and a half by two inches; weight four ounces. When packed in its leather case it can be easily carried in the pocket. It is adjusted to the

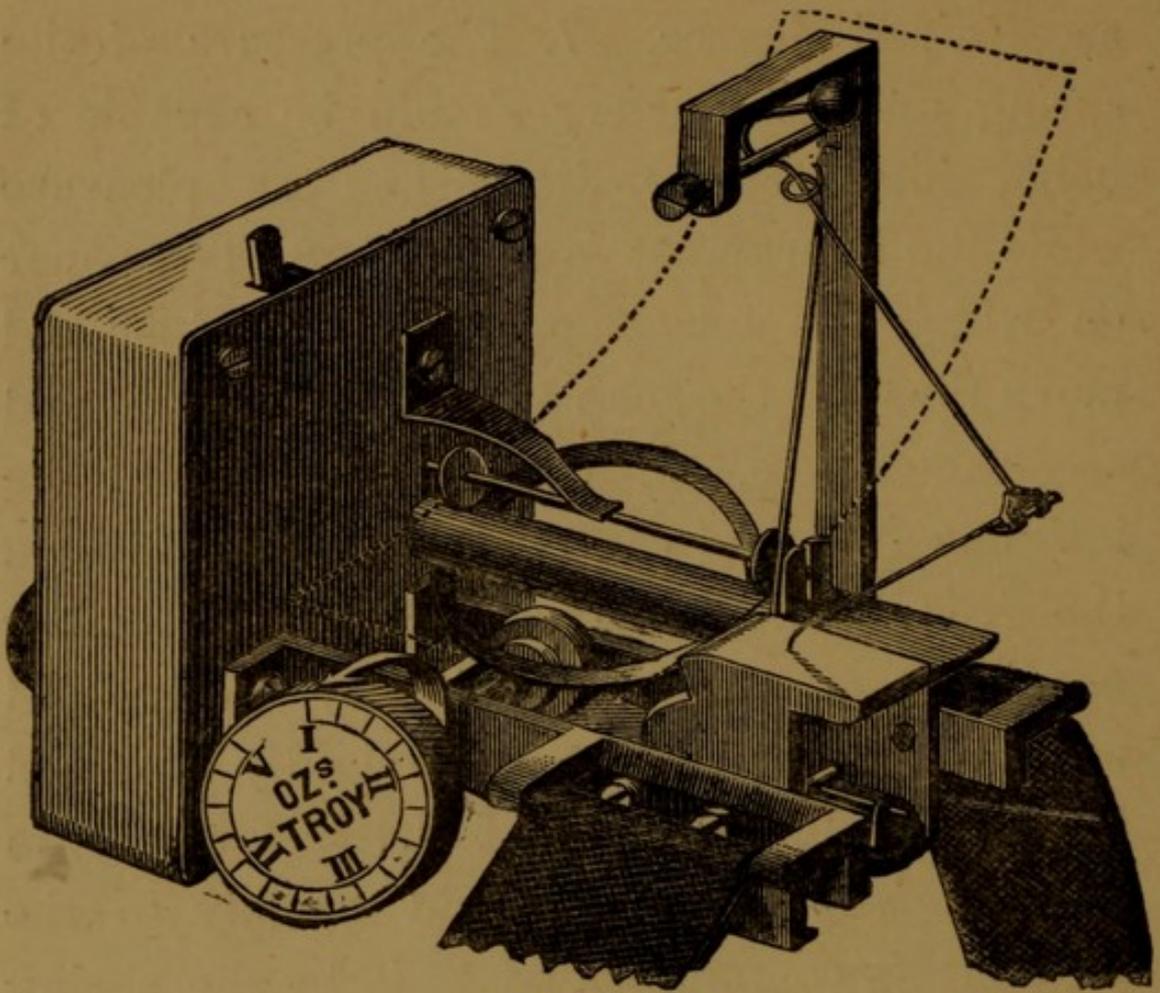


Fig. 1.

wrist, the stud on the free end of the spring being carefully placed upon the radial artery immediately above the styloid process of the radius. The instrument is kept in position by an inelastic strap, which may be secured by a tourniquet or simply held by the fore-finger and thumb of the right hand.\* The pressure of the spring is regulated by the excentric wheel, to any amount from one up to five

\* See Frontispiece.

ounces. When the needle is seen to play freely over the centre of the tracing-paper, the machinery of the clockwork which drives the paper through the machine is set in motion by pushing towards the right the small metal handle on the top of the clockwork box. The patient's arm needs no support except that given by the operator's hand which holds the strap; or if the tourniquet is used, the patient's arm may be steadied if needful by placing the hand under his fingers. No wrist-rest is required, nor is it even necessary to lay the patient's arm on a table. The instrument is used with equal facility on either arm, and the patient may either stand, sit, or lie. The levers are so adjusted that the movements of the artery are magnified exactly fifty times. The pressure of the spring may be altered without disturbing the instrument. The smoked portion of the paper passes through the instrument in ten seconds; hence six times the number of beats traced on the paper give the number of beats per minute. The clockwork box rests on the arm, and increases the stability of the instrument. As the lever to

which the needle is attached plays freely through a loop on the upright stem that is moved to and fro by the pulsations of the artery through the spring, the movement of the needle is perfectly free and rapid, so that the tracing is sharp and exhibits the slightest vibrations in the arterial movements.

The subjoined wood-cut (Fig. 2) shows the principal parts of my sphygmograph. A

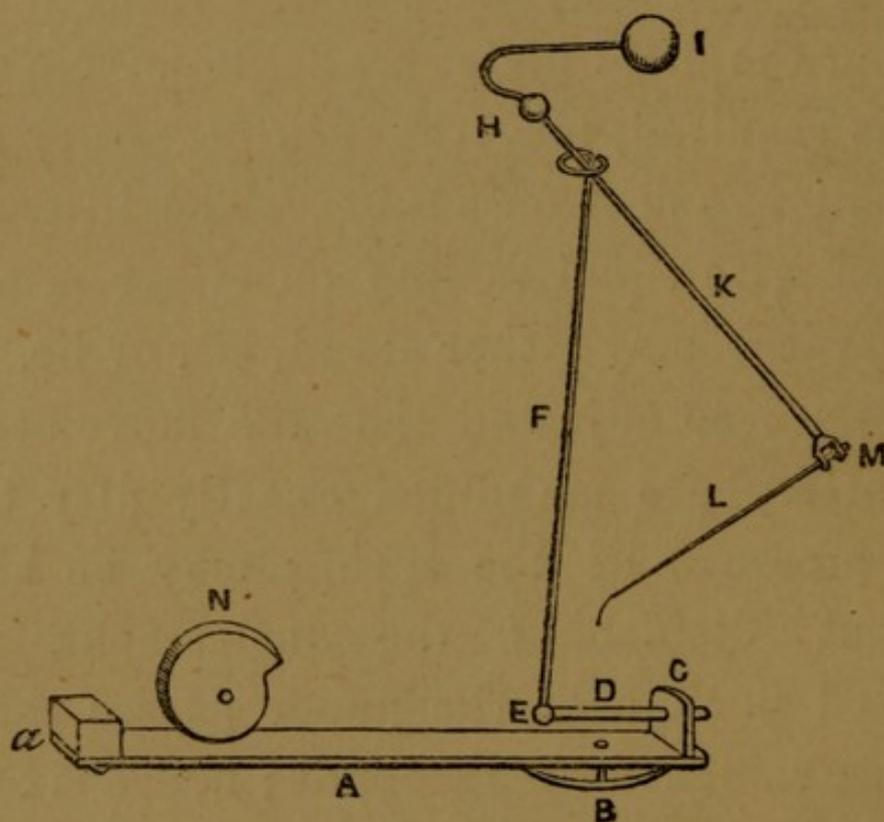


FIG. 2.

delicate steel spring *A* is firmly fixed at one end *a*. The other free end has attached

beneath it a rounded button B, which is placed upon and receives the movements of the radial artery. These movements are communicated to the short rod D, which is fastened to the spring above at its free end c. At right angles to D, and connected with it by the axle E, rises the upright stem F, which every upward movement of D causes to move forward. At the top of F is a loop in which the rod K lies. This rod is connected at the axle H with a bent rod having a counterpoise I. When the upright rod F makes a forward movement the oblique rod K also swings forward by the weight of its counterpoise. To the lower end of K the needle L is attached by the hinge M, and its point describes on the smoked paper, which is propelled by the clockwork machinery at a uniform velocity, a graphic representation of the movements communicated to it. The two rods F and K being long levers, magnify considerably (together fifty times) the movements communicated to the spring by the arterial pulsations. The downward pressure of the spring on the artery may be at pleasure increased from one up to five ounces by means

of the excentric *n*. By this arrangement sphygmograms of the weakest as well as of the strongest pulses may be taken, and the tracings are of the most accurate and delicate character.

Pulse-tracings or sphygmograms vary almost infinitely, revealing in their variations the different states of the circulation. A perfect sphygmogram consists of a number of different events indicated by strokes and curves. Fig 3, a sphygmogram taken from a healthy individual, shows all the curves of a perfect tracing :



FIG. 3.—Pressure 2 oz.

*a*, a vertical stroke upwards, usually called the systolic or percussion wave or stroke; *b*, apex of up-stroke; *c*, a downward stroke of varying length; *d*, a curve called the first tidal, or predicrotic, wave; *e*, an angle

called the aortic notch; *f*, a second curve called the aortic curve, or dicrotic wave; *g*, a slight curve called the second tidal wave. The downward stroke is continued to *h*, from which point the upward vertical systolic stroke recommences.

The explanation of these strokes and curves generally given is as follows:

The up-vertical stroke is caused by the sudden dilatation of the artery owing to the rush of blood from the heart through the aortic valves into the artery, produced by the contraction of the left ventricle. The down-stroke *c* is made by the contraction of the artery by means of the elasticity of its coats and the action of its circular muscular fibres. The curve *d* is said to be caused by a secondary wave of the blood following the systolic rush of blood. The notch *e* is held to indicate the termination of the systolic and the commencement of the diastolic action of the heart. The curve *f* is ascribed to a fresh wave caused by the sudden closure of the aortic valves. The curve *g* is made by a slighter wave following this dicrotic or aortic

wave. The horizontal or slightly sloping stroke from *g* to *h* indicates the period of rest before the recommencement of the systole.

Marey's explanation\* of the sphygmogram is as follows :

'Une première impulsion ventriculaire envoie dans le système artériel une certaine quantité de sang ; celui-ci, grâce à la vitesse dont il est animé, s'élançe, sous forme d'ondes, dans chacunes des artères qui émanent de l'aorte. De là le mouvement se propage dans une direction centrifuge et accuse son passage au-dessous du sphygmographe par un premier soulèvement du levier. Ce premier mouvement est à peine accompli, qu'un autre lui succède dans des conditions semblables, mais avec une intensité moindre. C'est l'onde secondaire ou *dicrote*, dont la direction est également centrifuge ; parfois une troisième onde apparaît à la suite des deux autres, mais il faut, pour qu'elle ait le temps de se produire, que le cœur n'envoie pas trop vite une nouvelle quantité de sang. . . . Ces ondes sont toutes centrifuges.'

According to Marey, then, all the curves on the downward stroke are caused by waves of blood. This is the opinion generally held by writers on the subject.

Landois,† on the other hand, does not allow that any of the curves on the downward stroke are caused by a wave of blood except the dicrotic curve *f*. The others, *d* and *g*, he

\* *Op. cit.*

† *Op. cit.*

considers to be due to the elasticity of the artery. Here I think he is right.

My explanation of the normal sphygmogram is as follows :

The vertical up-stroke *a* is caused by the distension of the artery by the blood projected into it by the contraction of the ventricle. When the full distension is reached, the artery contracts and causes the downward line *c*. This contraction forces the blood back ; but as the aortic valves now close, a wave of blood reflected from the valves returns down the artery forming the dicrotic curve *f*. But as this takes some time to return, and as the artery is still full of blood, the elasticity of the artery is slightly overcome and the artery is slightly elevated, to be immediately again depressed by the elasticity or the circular muscle of the vessel, forming the predicrotic wave *d*, which is sharply arrested at the so-called aortic notch *e*, by the back-stroke wave which forms the curve *f*. Another slight elevation occurs at *g*, again due to the oscillation of the elastic artery.

That this is the true explanation of the figures of the normal sphygmogram I think

can be proved by taking tracings of the pulse of the same subject on arteries at different distances from the heart.

The subjoined tracings were taken in succession from the left carotid (Fig. 4), the left



FIG. 4.—Left carotid, pressure  $1\frac{1}{4}$  oz.

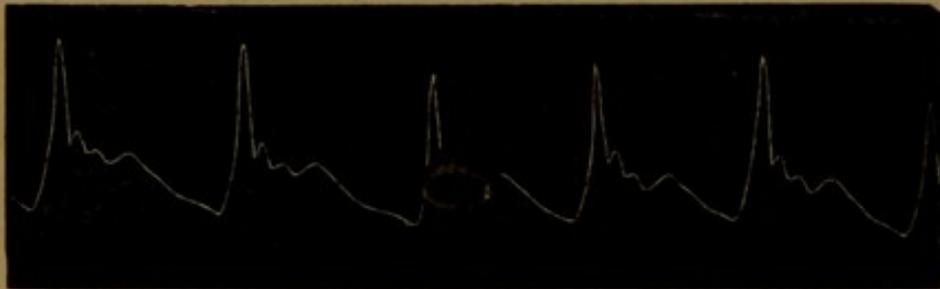


FIG. 5.—Left radial, pressure 2 oz.



FIG. 6.—Left dorsal foot artery, 2 oz.

radial (Fig. 5), and the dorsal artery of the left foot (Fig. 6) of the same person.

It will be noticed that while the so-called

tidal wave preserves the same relation to the upright systolic or percussion stroke in all three tracings, the so-called dicrotic wave occurs soonest in the tracing from the carotid (Fig. 4), and comes on later as the artery is more distant from the heart, the period at which it occurs being latest in the tracing from the foot artery, which is farthest from the heart. This proves that the curve called 'tidal wave' is not caused by a blood-wave, but is an oscillation of the artery caused by its elasticity or muscular action, and that the so-called dicrotic curve is caused by a blood-wave produced, as Landois asserted, by the back-stroke of the blood on the closed aortic valves. In some tracings I have obtained from the foot artery, the second so-called tidal wave is seen to precede the dicrotic curve, showing that the time occupied by the back-stroke of the blood-wave was so considerable that the second arterial oscillation occurred before it could reach the distant artery.

The oscillatory character of the first wave is often well shown in the sphygmogram, as in the subjoined tracing (Fig. 7).

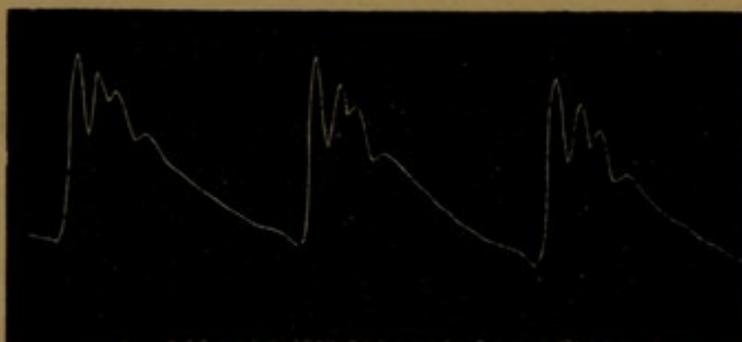


FIG. 7.—Pressure 3 oz.

The first event of the sphygmogram, the *percussion-stroke* (*a*, Fig. 3), is usually vertical in an ordinary healthy tracing. Sometimes, however, it is distinctly curved, as in this tracing



FIG. 8.—Pressure 3 oz.

(Fig. 8). Here the first portion of the ventricular systole was evidently slower than the last.

Or it may be curved in a different way as in Fig 3, where the first portion of the stroke is vertical, but the latter part is slightly curved towards the right. Here the last portion of the ventricular systole was slower than the first.

Or the curve may be double, making the percussion-stroke a wavy line, as in this tracing

(Fig. 9). Here the first and last part of the ventricular systole are slower than the middle portion.

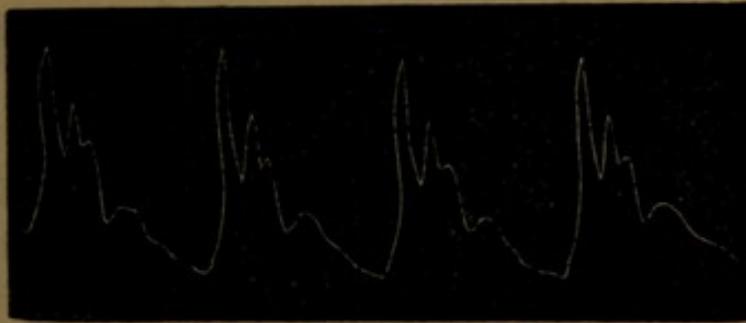


FIG. 9.—Pressure  $2\frac{1}{2}$  oz.

These curvatures of the up-stroke bear out the idea that the contraction of the ventricle is of a peristaltic character, *i.e.*, that it takes place in successive acts of contraction.

Or the up-stroke may be altogether sloping, as on the subjoined tracing (Fig. 10). This indicates a slow feeble systole.



FIG. 10.—Pressure 2 oz.

The second event of the sphygmogram is the descent of the needle, indicating the subsidence of the artery. In the normal pulse (Fig. 3)

the elasticity or contractility of the arterial coat causes the descent to take place immediately when the percussion-stroke has attained its highest point, and the consequence is a very acute angle from the apex (*b*). If the contractile power of the artery is great, as in young persons generally, the descent of the needle is very considerable (Fig. 5). In some cases, of young persons especially, the descending stroke may even go lower than the starting-point of the percussion-stroke, as in the subjoined tracing (Fig. 11).

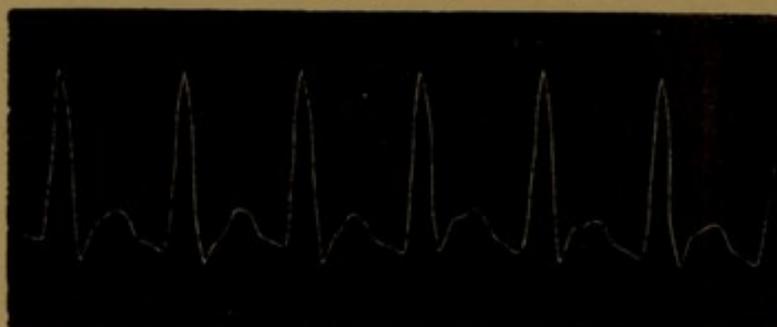


FIG. 11.—Pressure 2 oz.

This low descent of the needle is also sometimes observed in the tracings taken from a person who has just swallowed a considerable quantity of alcoholic stimulant. It is likewise occasionally seen in the dirotic pulse of chlorosis, and of typhoid or hectic cases.

On the other hand, the descent of the needle

may be merely indicated by a slight notch at the apex of the percussion-stroke, after which the needle continues to ascend, as in the subjoined tracing (Fig. 12). This indicates a very



FIG. 12.—Pressure  $1\frac{1}{2}$  oz.

feeble contractility of the artery, which after a weak contraction continues to rise with the current of blood forced into it by the systole of the ventricle. This character is only met with in old persons, or such as are enfeebled by disease. It may indicate an atheromatous condition of the arterial coats.

The third event of the sphygmogram is the curve called generally tidal wave, but which should rather be termed the first arterial oscillation. It may be a simple curve, as in Figs. 3, 4, 6, 8, 10; or it may be a double oscillation, as in Figs. 5, 7, 9. (Figs. 4, 5, and 6 show that it may be single in some, and double in other arteries of the same person.) Instead of a curve it may present

the appearance of a sharp angle, as in the subjoined tracing (Fig. 13), taken from a young woman suffering from albuminuria and some hypertrophy of the left ventricle.

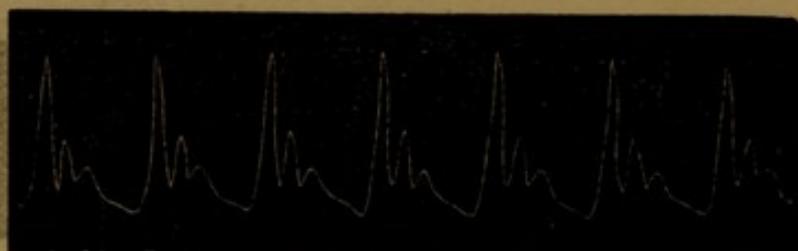


FIG. 13.—Pressure 2 oz.

The fourth event of the sphygmogram commences at what is termed the aortic notch (*e*, Fig. 3), which is usually held to indicate the moment of closure of the aortic valves. In fact the aortic valves close when the ventricle has emptied itself by its systole and the stream of blood is met by the contractile action of the arteries. The contraction of the arteries causing the blood to impinge on the aortic valves, a wave is created that is propagated through the arteries, causing them to rise and form what is called the dicrotic curve. The position of this wave, as I have pointed out, varies with the distance of the artery from the heart. The nearer the heart, the sooner does the curve appear; the more distant the

artery, the later it occurs, as is seen in Figs. 4, 5, and 6. When the tracing is taken at the wrist, the dicrotic-wave curve follows close upon the third event or first arterial oscillation, but when the tracing is taken in the foot, there is a distinct interval betwixt the arterial oscillation curve and the dicrotic curve.

The fifth event of the sphygmogram is what has been termed the second tidal wave, but which I propose to term the second arterial oscillation, as I believe it to be merely owing to a slight vibratory contraction of the artery. It is never very well marked, and is scarcely visible in most tracings, but is tolerably well seen in the subjoined sphygmogram from a robust man of fifty (Fig. 14).

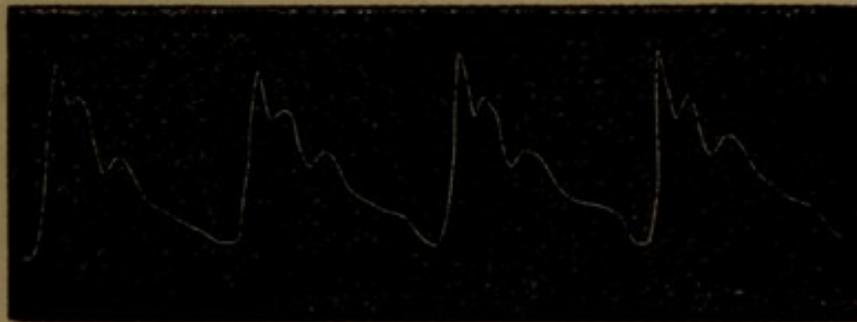


FIG. 14.—Pressure 2 oz.

In tracings of the radial artery it occurs after the dicrotic wave; but when the latter is delayed, owing to the artery being more dis-

tant from the heart, as in the artery of the foot, it either precedes the dicrotic wave-curve or is annihilated by the latter, or it becomes mixed up with the dicrotic wave, giving the curve of the latter a wavy appearance, as shown in the subjoined tracing (Fig. 15).

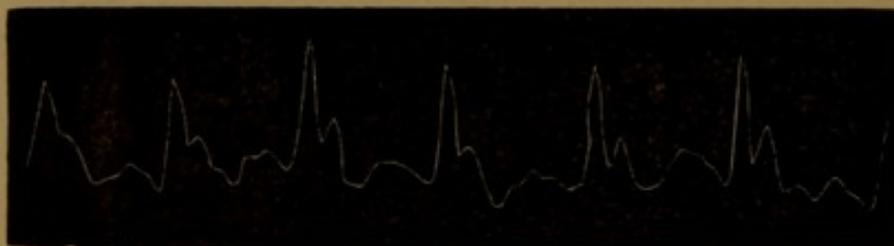


FIG. 15.—Pressure  $2\frac{1}{4}$  oz.

In the normal pulse none of the curves observed in the down-stroke are caused by a reflux of the blood or a blood-wave proceeding from the periphery to the heart. The sphygmogram made by a radial artery in which the circulation is stopped by pressure immediately beyond the stud of the sphygmograph, does not display any essential difference from a tracing made by the same artery when the circulation is unimpeded. The circulation in the artery was arrested by pressure just beyond the instrument when the subjoined tracing was obtained (Fig. 16). It may be

compared with Fig. 5, which is a tracing got from the same radial artery in which the cir-



FIG. 16.—Pressure 2 oz.

ulation was unhindered. This shows that in the normal pulse no resistance is offered to the free flow of the blood through the capillaries.

In certain conditions of the circulation the normal curves are absent, and are replaced by a series of vibrations giving rise to what is termed a polycrotic sphygmogram. Subjoined is a specimen of this tracing from a patient in the cold stage of ague (Fig. 17).



FIG. 17.—Pressure  $4\frac{1}{2}$  oz.

A similar appearance is sometimes observed in the weak nervous pulse of debility.

The sphygmogram may consist of only three events, the systolic up-stroke, the descent un-

broken by any arterial vibration, and the dicrotic curve. This constitutes what is called the dicrotic pulse. It is observed in cases of typhoid, hectic, and other low febrile states, also occasionally in chlorosis. The subjoined tracing is from a case of mild typhoid fever (Fig. 18).

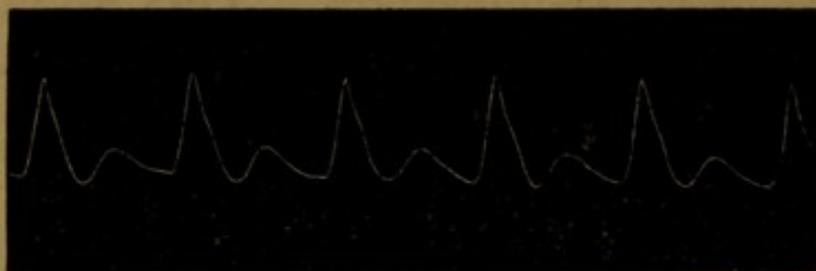


FIG. 18.—Typhoid, 8th day; temp.  $103.5^{\circ}$ ; pressure 2 oz.

In the dicrotic pulse the descending line may even be carried below the starting-point of the systolic up-stroke, as in the following tracing (Fig. 19).



FIG. 19.—Severe typhoid, 26th day.

The next tracing is from a patient in the last stage of florid phthisis (Fig. 20).



FIG. 20.—Pressure 2 oz.

Subjoined is a tracing from a chlorotic girl of nineteen. Here the dicrotism is not complete, for indications of the arterial vibrations may be detected (Fig. 21).



FIG. 21.—Pressure 2 oz.

In cases of dicrotism the artery seems to have lost its active contractility; and its distension by the blood propelled by the systole of the heart seems to be followed by a sort of passive collapse, the artery seeming to be quickly emptied owing to the dilated and lax condition of the capillaries. The back-stroke wave from the closed aortic valves produces a second distension of the lax artery, that is sometimes nearly half as high as the first systolic stroke. The quick pulse of mild py-

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rexia will often present the dicrotic character, as in the subjoined tracing (Fig. 22).

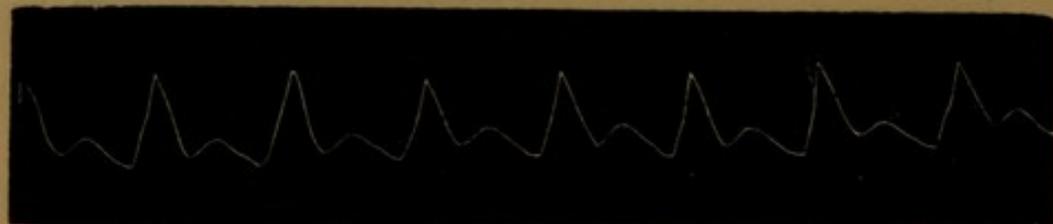


FIG. 22.—Pressure 2 oz.

Some writers on sphygmography assume that valvular diseases of the heart will communicate definite characters to the sphygmogram, and they give tracings which seem to prove this. I am not now going to criticise what other writers on sphygmography have asserted, but I might easily show from my own collection of sphygmograms that tracings said to be characteristic of mitral and aortic valvular diseases are frequently made by pulses of subjects where no such valvular imperfections exist, and, on the other hand, the pulse-tracings in cases of marked mitral or aortic-valvular disease often do not differ from normal sphygmograms. The following tracing (Fig. 23), made by the radial pulse of a case of disease of the aortic valve, with loud diastolic murmur, is identical with the sphyg-

mograms of many subjects without any cardiac imperfections.

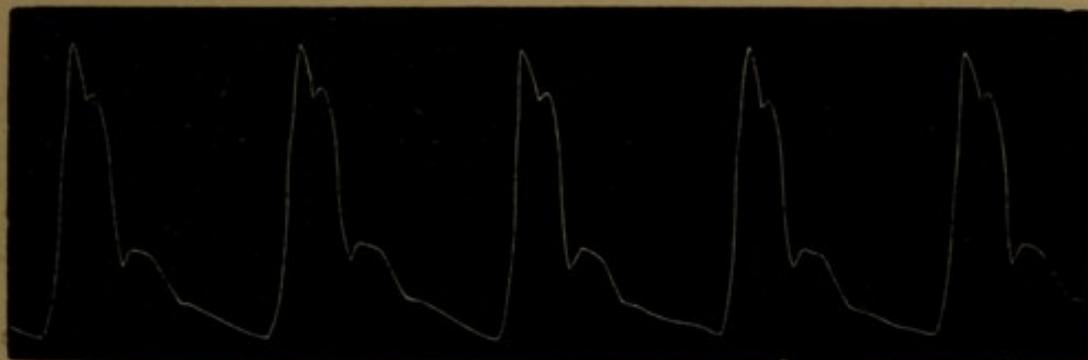


FIG. 23.—Pressure  $2\frac{1}{4}$  oz.

It may be compared with the next tracing (Fig. 24), where there was similar audible

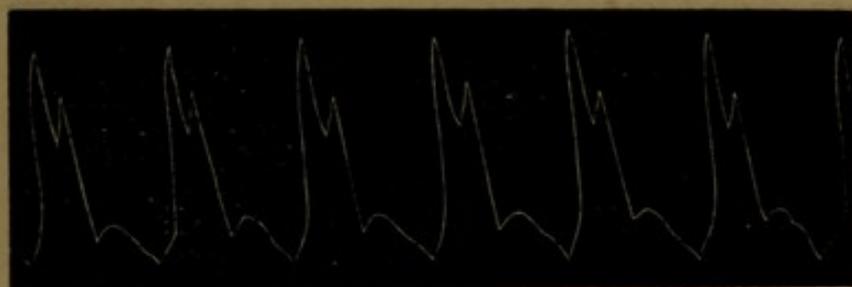


FIG. 24.—Pressure 2 oz.

evidence of aortic valvular lesion, and where the diastolic curve is small relatively to the size of the tracing; and the next tracing

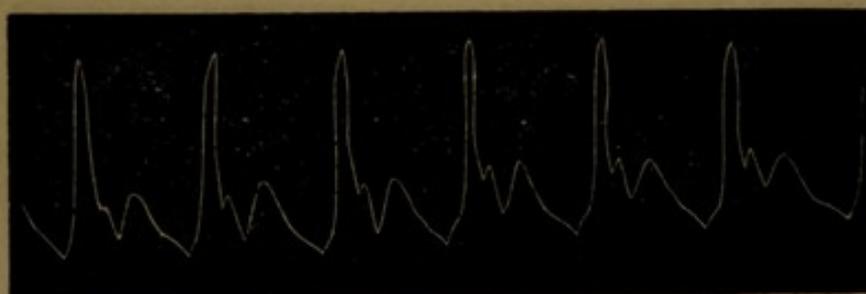


FIG. 25.—Pressure 2 oz.

(Fig. 25), given by the radial artery of a case

of marked mitral insufficiency, differs in no appreciable degree from the sphygmograms of many cases of irritable heart.

The subjoined curious tracing (Fig. 26) from the pulse of a woman of forty, who had had rheumatic fever eighteen years previously, and in whom there was a strong diastolic murmur,



FIG. 26.—Pressure 3 oz.

bears a striking resemblance to the sphygmogram of another woman, who had no signs of valvular disease (Fig. 27).

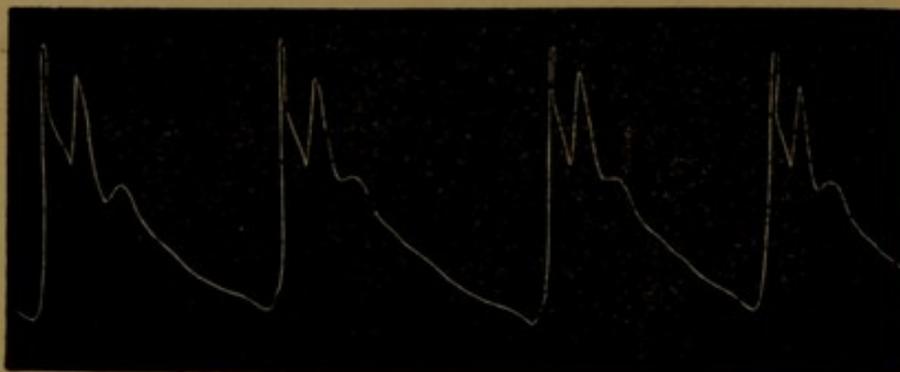


FIG. 27.—Pressure 2 oz.

The subjoined tracing (Fig. 28) is very similar to one given by B. Sanderson at

p. 78 of his 'Handbook of the Sphygmograph,' as characteristic of rheumatic val-



FIG. 28.—Pressure  $2\frac{1}{4}$  oz.

vular disease with large mitral regurgitation, and yet there was no sign of valvular disease in the patient, and at other times his tracing was nearly normal, as seen here (Fig. 29).



FIG. 29.—Pressure  $2\frac{1}{4}$  oz.

Such cases as these—and they might be multiplied almost indefinitely—show that the sphygmograph cannot be relied upon to enable us with certainty to discover organic affections of the heart. The same conclusion has been arrived at by Sanderson, who says:\* 'It is

\* *Op. cit.* p. 65.

not likely that the instrument will ever be of much use in the discovery of organic lesions.' And in another place he says :\* ' Affections the most diverse communicate to the pulse the same graphical characters ;' and he might have added : in many cases of well-marked organic disease the sphygmograms may present all the features of normal pulse-tracings.

But though the sphygmograph will not enable us to determine with certainty if there be organic heart-lesions, still less to decide what those lesions are, it will give us information on other points connected with the circulation not less important. Sanderson† says :

' Its use is to enable the physician to investigate the state of the circulation and circulatory organs in diseases of which the general nature is already recognised, with reference to (1) the mode and direction of the contraction of the heart ; (2) the soundness of the arteries ; and (3) the relative quantity of blood contained in the arteries and veins, or, in other words, the balance of pressure between the venous and arterial systems.'

It will likewise enable us to analyse the quality of the heart's actions in cases of tumultuous or excessively rapid action, which

\* *Op. cit.* p. 27.

† *Loc. cit.*

neither the finger nor the ear can properly judge. I give here (Fig. 30) the sphygmogram of a case of abnormal heart's action, which neither palpation nor auscultation could make anything of. It is that of a little girl of three years of age. It will be seen that



FIG. 30.—Pressure 2 oz.

the heart's action is as it were duplex, a vigorous normal beat being interrupted immediately after the dicrotic wave by a feebler beat of a more distinctly dicrotic character. The pulse in this case always maintained precisely the same character of regular irregularity when examined at intervals of weeks and months. To this kind of pulse the term 'bigeminous' has sometimes been applied, and it is said to be frequently observed in digitalis poisoning.

Extreme irregularity of the tracing is met with sometimes during a fit of asthma, as in the

subjoined (Fig 31). When the asthmatic fit was over the tracing became normal.



FIG. 31.

Extensive effusion into the pericardium will often cause an altogether anomalous tracing such as is here displayed (Fig. 32).



FIG. 32.—Pressure  $2\frac{1}{2}$  oz.

In intermittent pulses the tracing during the intermission descends below the general level of the tracing, and the next systolic up-stroke rises higher than the others as on the next sphygmogram (Fig. 33). This tracing also shows that



FIG. 33.—Pressure 2 oz.

the intermission is sometimes interrupted by an abortive attempt at an up-stroke as though there was a slight and altogether insufficient systolic contraction during the intermission. The low descent of the needle shows that during the intermission the artery becomes more emptied of blood than during the normal pulsations. When the abortive up-stroke occurs in the intermission, the descent of the needle is not so low as in intermissions without this partial refilling of the artery.

Tracings from the pulses of patients suffering from the same disease will often show great differences. Subjoined are sphygmograms from two cases of exophthalmic goitre. Fig 34 is that of a case where the heart-symptoms, though marked, were not so developed as in Fig. 35. The latter figure illustrates the preciseness with which the most rapid pulsations are graphically represented by the sphygmograph. This pulse was going at the rate of 192 beats per minute.

In some cases the tracing made when the patient is seated differs greatly from that made when he is standing or lying. This is particu-

larly the case when there is great irritability of the heart. The tracing is sometimes largest in the lying position, but sometimes it is largest in the standing position. Fig. 34 was taken when the patient was standing; the tracing was much lower when the patient was seated.



FIG. 34.—Pressure 4 oz.



FIG. 35.—Pressure 4 oz.

In the examination of cases, especially new ones, it is well to take tracings of both radial arteries. If we observe a marked difference we may probably discover some reason for this. Subjoined are tracings from the left



Fig. 36.—Pressure 3 oz.

(Fig. 36) and right (Fig. 37) of a patient.



Fig. 37.—Pressure 3 oz.

There was an aneurismal tumour under the right clavicle. From the sphygmograms it was rightly inferred that the aneurism was of the innominata, not of the aorta.

I might easily give from my own experience many more varieties of sphygmograms; but my object in this little essay is not to write a treatise on sphygmography, but rather to give some instructions as to the mode of using the sphygmograph I have introduced into medical practice, and to show by a few examples how useful it may be as an aid to the diagnosis of affections of the circulation. A very little practice will enable the practitioner to take a correct tracing of any pulse as rapidly as he can feel the pulse in the ordinary way with the finger. As the instrument gives us an indelible autograph of the pulse with all its peculiarities,

it provides us with a perfect history of the variations of the circulation during the whole course of a disease, a history to which we can always refer for the purpose of comparison. Every pulse in health, and still more during disease, will occasionally present variations, The pulse of a healthy person varies according to the conditions in which he is. The sphygmogram is not the same when he has been long resting as it is just after exercise. It is different when he is fasting and when he has eaten a good meal. It is altered by stimulants, by mental emotions, by fatigue, by position, by changes of temperature. These alterations may be as regards the relative shape or size of the different events of the sphygmogram, or as regards the strength of the pulsations. At one time the largest tracing will occur under a slight pressure of the spring, at another under a greater pressure. But the pulse of the same person in health under all circumstances will generally offer some more or less striking peculiarities that differentiate it from other pulses, so that we may almost recognise an acquaintance by his sphygmogram

as surely as we can by the features of his face.

In taking sphygmograms particular attention must be given to the regulation of the pressure of the spring. The rule is to vary the pressure of the spring when the instrument is applied to the wrist, so that the needle describes the longest up-stroke on the paper, before the clockwork is set in motion. It will be found, and can be seen from the above tracings, that different pulses require different degrees of pressure. But the pulse of the same person will require different pressures at different times. When fatigued or fasting the artery may not be able to make a satisfactory tracing with more than one and a half ounce pressure; whereas when the subject is fresh and well-fed the best tracing will perhaps be made under a pressure of three or four ounces, a pressure which would almost have extinguished the pulse in his feeble state. In disease, too, the pulse will sometimes lift a greater, sometimes a smaller weight than in health. A little practice will enable the operator to adjust the pressure of the spring easily so as to get the best sphygmogram from every pulse.

All wrists are not equally well adapted for obtaining good characteristic sphygmograms. The best tracings are got when the radial artery lies at a moderate depth. When deeply sunk among the tissues, as is the case in most fat persons, it is more difficult to obtain a good tracing. Here, not only is it necessary as a rule to apply more pressure to the spring, but the band of the instrument must be drawn more tightly round the wrist. The radial artery is sometimes too small to make a good tracing; in such cases the ulnar artery will sometimes be found better for the purpose. The course of the radial artery is frequently abnormal. I have several times seen it running on the dorsal aspect of the wrist, where, however, the instrument can be readily applied and a satisfactory tracing obtained. The course of the radial artery is sometimes tortuous; in such cases if care is not taken the foot of the instrument may press on the artery and impair the sphygmogram. In very lean subjects the artery often lies very superficially, and unless the heart's action is vigorous, a strong pressure of the spring may easily extinguish the pulse

altogether. The wrists of strong athletic young men are generally so encumbered with stiff prominent tendons that it requires some practice to be able to get the instrument properly applied to the artery. In such cases it will often be found advantageous to flex the wrist a little, whereby the cord-like tendons are relaxed and access to the artery obtained.

In judging of the quality of sphygmographic tracings we should bear in mind that in the young the systole of the heart is usually quicker and the contractility of the artery greater than in adult life or middle age; hence the up-stroke of the tracing will be more vertical and the subsequent down-stroke greater in the former than the latter, as will be seen by comparing Figs. 4, 5, 6, 11 with Figs 3, 14. In old age, again, the elasticity of the artery is often defective, and though the systole may be strong—there being usually hypertrophy of the ventricle when the arterial coats are stiff in old age—giving a vertical upright stroke, the next event, the down-stroke, is often very small, as seen in the tracings from old pulses, such as Fig 12.

When we find a pulse of middle age giving a tracing resembling that of the healthy pulse of youth, we may infer that there is something wrong with the circulation. Similarly when the youthful pulse-tracing resembles that of mature or old age, this shows a departure from healthy action.

Those commencing the study of sphygmography should make themselves thoroughly acquainted with the pulse-tracings of healthy persons at all periods of life and under various conditions, and thus learn the variations of the normal tracing. A considerable amount of practice is required in order to enable the operator to obtain the best tracing from every pulse. If the instrument is not exactly applied to the artery, if the pressure of the spring is not duly regulated, and if the strap encircling the wrist is held too loosely or too tightly, a tracing will be obtained which is not the true sphygmogram of the case. When a doubt exists the tracing should be repeated, with a more careful adjustment of the instrument; and it will often be found that the sphygmogram which at first appeared abnor-

mal, will be perfectly normal. When the sphygmogram presents a rounded apex, this is often owing to a faulty application of the instrument; a more careful adjustment, or a different pressure of the spring, will generally elicit a sharp apex.

Sphygmography, like every other art, requires to be learned, and practice alone will make the operator perfect in the art. The more perfect the instrument the easier will be the acquisition of the art; and I believe that my instrument will be found to give better results, and dexterity in its use be more easily acquired, than any other instrument hitherto offered to the profession. I do not doubt that some more perfect instrument may hereafter be invented, but I claim for it a decided superiority over all those hitherto in use.

I must warn the practitioner against expecting too much from the revelations of the sphygmograph. The writers on sphygmography usually err in making dogmatic assertions relative to the characteristic sphygmograms of various morbid conditions of the circulation. I have shown above that con-

siderable valvular disease of the heart may exist, and yet the pulse-tracing may be normal; and on the other hand, that very abnormal tracings may be obtained when there is no organic disease of the heart.

Our experience is yet too limited to enable us to estimate the precise value of sphygmography as an aid to diagnosis; but when the employment of the sphygmograph becomes pretty general, when accurate observers shall use it in their daily practice, its teachings will eventually be accurately appraised, and it will play as important a part in clinical research as the stethoscope and the thermometer. It will be a satisfaction to me if by the introduction of an accurate, portable, easily-used, and inexpensive instrument, I may succeed in popularising the practice of sphygmography, the advantages of which have hitherto been mostly confined to hospital patients, but have been almost entirely withheld from the much more numerous patients of private practice.

## APPENDIX.

---

I MAY give here the special directions I have drawn up for the use of my pocket sphygmograph.

### *Directions for Use.*

1. Wind up the clockwork used to drive the smoked paper along by means of the milled button at the back of the clockwork box.

2. Insert one end of the smoked paper (smoked side uppermost) on the right-hand side of the instrument, between the roller and small wheels.

3. Make the patient hold out either hand open and in an easy position, the fingers pointing towards you, and direct him not to move the wrist or fingers.

4. Ascertain the precise spot where the radial artery beats at the wrist, close behind the eminence of the os trapezium.

5. Slip the band, the free end of which has been drawn through the clamp, over the patient's hand.

6. Apply pressure to the spring by turning the spring-regulator so that the number of ounces, or portions of ounces, you wish is pointed to by the indicator. The pressure may be altered at will when the instrument is fixed on the arm.

7. Place the bulging button of the spring exactly over the artery, its long axis parallel to the course of the artery, the box containing the clockwork resting lightly on the forearm above.

8. Retaining the instrument in its place with the left hand, draw the band through the clamp with the thumb and forefinger of the right hand, holding back the clamp with the other fingers of that hand; when the requisite tightness has been obtained, which will be known by the point of the needle working freely over the centre of the smoked paper, screw up the clamp with the left hand, so as to fix the instrument.

9. Set the smoked paper in motion by push-

ing towards the right the small handle on the top of the clockwork box.

10. Let the paper run through, and do not touch the instrument or the patient, unless to support his hand in your own right hand to secure perfect steadiness.

11. Catch the paper as it passes out of the instrument in your left hand.

12. Stop the clockwork as soon as the paper has passed.

*Remarks.*—The clockwork is regulated so that the smoked paper shall pass through in ten seconds. Six times the number of pulsations traced on the paper will give us the number per minute. The clockwork will not pass more than three lengths of paper at the same rate. It is best to wind it up anew after two lengths have passed.

For ordinary purposes the instrument may be used without fixing the band in the clamp, both ends of the band being merely held with sufficient tightness at the back of the patient's wrist by the fingers of the operator's right hand.\* A very little practice will enable the

\* See Frontispiece.

operator to hold the instrument thus as steadily as the clamp can do it, and time is thereby saved.

*Directions for Making the Smoked Paper.*

1. A stiff, smooth, white wove writing-paper is cut into strips six inches in length and one inch in breadth: any bookbinder will do this.

2. Place one of these strips in the tin-plate holder, which covers half an inch of each end.

3. Take a piece of camphor about the size of a bean, put it on the bottom of an inverted tea-cup or other convenient place, and ignite it.

4. Pass the paper in its holder several times rapidly *over the top of the flame*, not in the flame, as this would burn in the smoke and prevent the needle removing it easily. We thus get a strip of paper with five inches of its surface properly smoked and ready for use.

5. When the tracing has been made, write on the paper with something pointed, *e.g.* a toothpick, the patient's name, his position ( | standing, — lying, / sitting), the pressure

of the spring, the date, and any short note you wish to make.

*Remarks.*—It is best to make these smoked papers at home, and to carry them to the patient's house in the small box provided for that purpose, and to replace them in the box when the tracing is made in order to convey them home to be varnished.

*Directions for Varnishing the Smoked Papers.*

Anyone of the many different quick-drying varnishes may be used for the purpose. I have found one of the best to be that used by photographers, called *Crystal Varnish*, or a good simple varnish may be made with 1 oz. *Gum Damar* to 6 oz. *rectified Benzoline*. A glass vessel about six inches high and one and a quarter inch in diameter is filled with this varnish, and the smoked paper dipped into it for a second and then withdrawn. The varnished paper, smoked side uppermost, is then laid on a piece of blotting-paper. In two minutes it is perfectly dry, and ready for fixing in the case-book.

I must here acknowledge my obligations to Mr. J. Ganter in the construction of this sphygmograph. His technical skill as a practical watchmaker and his mechanical ingenuity enabled him to overcome all the difficulties that presented themselves in carrying out the details of this very portable and easily-applied instrument. Mr. Ganter now devotes himself to their manufacture, but does not himself at present sell them by retail. They may be obtained through the principal surgical-instrument makers, but as the various fine adjustments require great care and skill, I would advise all purchasers to see that the instruments they buy are of Mr. Ganter's own make, which will be the best guarantee of their accuracy and excellence. Should the instrument get accidentally broken, any watchmaker can repair it. I have had one in daily use for eighteen months, and it has never needed any repair.

THE END.

