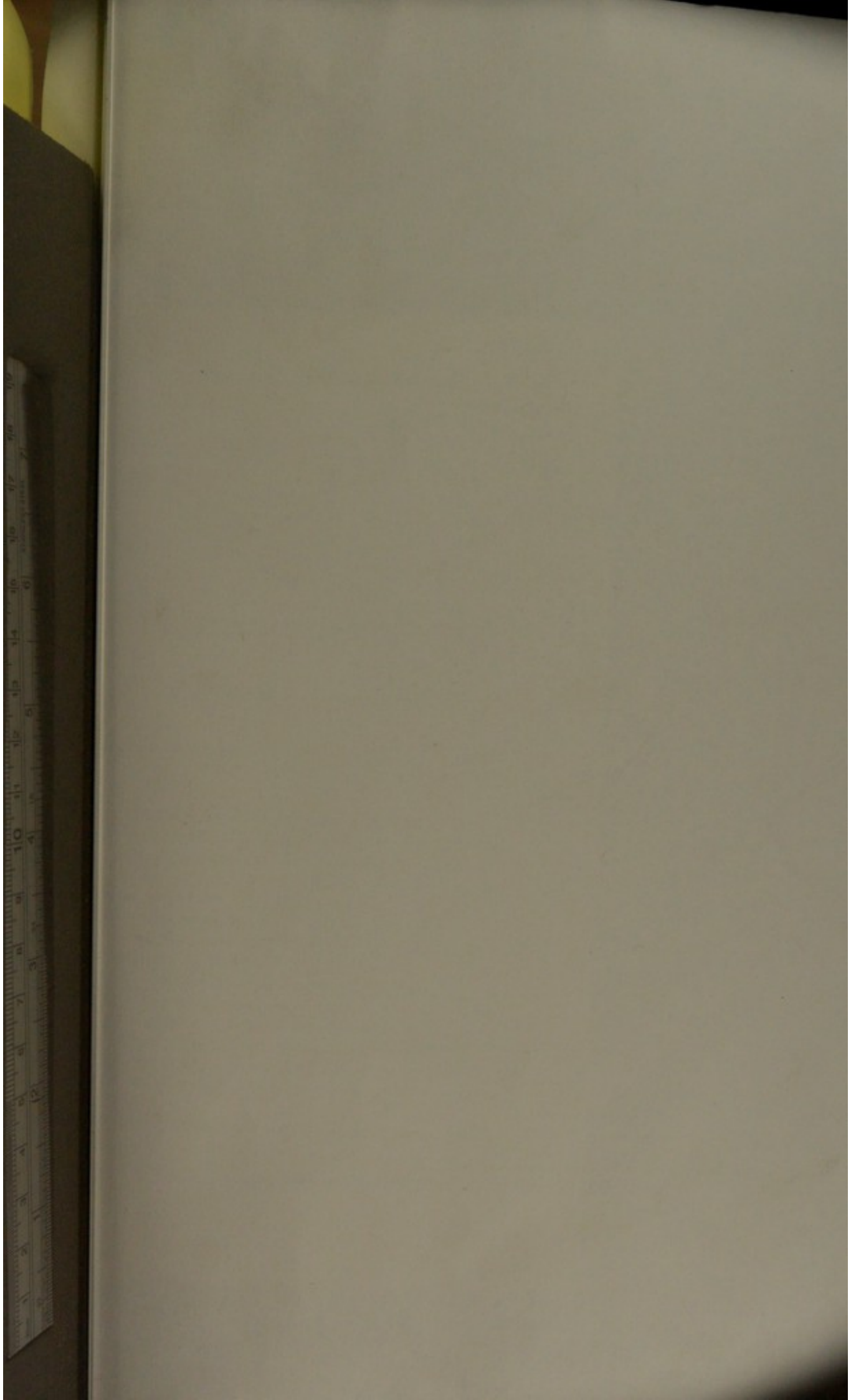
A new sphygmomanometer / by G. A. Gibson.



A NEW SPHYGMOMANOMETER*

By G. A. Gibson, M.D., D.Sc., LL.D.

The numbers in brackets refer to the "List of Authorities" given at the end of the paper.

It is unnecessary to enter fully into the history of the sphygmomanometer. Tigerstedt (1), Hill (2), Vaschide and Lahy (3), and Janeway (4) have collected the numerous works on the subject. It will suffice to mention the experiment of Hales (5), who measured the arterial pressure in the horse by the height to which the blood rose in a vertical tube connected with the artery, and the observations of Poisseuille (6), and Ludwig (7), who respectively introduced and improved the method of estimating arterial pressure by means of the mercurial manometer, which has since undergone many subsequent improvements. To obviate some of its disadvantages, Chauveau and Marey (8) and Fick (9) introduced elastic or spring manometers, which have passed through many alterations.

The arterial pressure has been obtained from the limbs

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in man by the kymograph on a few occasions during amputations. Faivre (10) carried out investigations of this sort, but these must be condemned as absolutely unjustifiable.

The first steps in the clinical estimation of the arterial pressure were made by Vierordt (11), who employed his own sphygmograph, weighted in order to determine the amount of pressure necessary to obliterate the pulsation of the radial artery. Marey (12), Waldenburg (13), von Basch (14), Hoorweg (15), Potain (16), Hürthle (17), Bloch (18), Mosso (19), Oliver (20), Riva Rocci (21), Hill and Barnard (22), Gärtner (23), Stanton (24), Cook (25), Erlanger (26), and Janeway (4) have, since his time, introduced different forms of clinical sphygmomanometers, which may be classified either in respect of their mode of application, or as regards the principles of their construction.

The sphygmomanometers of von Basch and Potain, as well as Oliver's earlier instrument and the smaller instrument suggested by Hill and Barnard, estimate the pressure by application directly to the radial artery. The three first-mentioned register the pressure by means of an aneroid, and the other by the resistance of the air compressed in the upper part of the tube. The instruments of Riva Rocci, Stanton, Cook, Erlanger, and Janeway employ the method of circular compression of a limb, so as to obliterate the lumen of one of the larger arteries and estimate the effects by examination of itself, or one of its branches, further from the heart; those of Marey, Hürthle, and Mosso act by embracing the extremities after the manner of the plethysmograph. The tonometer of Gärtner gauges the pressure, after compressing a finger, by the return of colour to the skin. It may be said at once that, with the exception of the sphygmomanometers which employ the method of circular compression of one of the larger limbs, there is none which need be seriously discussed. The others only possess historic interest. The larger instrument of Hill

and Barnard registers its results by means of an aneroid, and the later instrument of Oliver (20) by the use of a tube of spirit. Both of these employ the method of circular compression.

The methods of Riva Rocci, Martin, Cook, Stanton, and Janeway yield an accurate determination of systolic pressure, and give an approximate estimate of diastolic pressure. The larger instrument of Hill and Barnard, and the earlier apparatus of Oliver, in which the arterial pressure is gauged by the maximum excursions recorded, were believed to register the mean pressure within the vessel; the theory being that when the pressure surrounding the vessel and that within it are equal, oscillations attain their maximum. It has, however, been absolutely proved by Howell and Brush (27) that the maximum oscillations indicate diastolic pressure. The sphygmomanometer of Erlanger is based upon the same principles as that of Riva Rocci, and gives systolic and diastolic readings; it is the earliest attempt to furnish graphic records of arterial pressure in clinical investigation. It is fully described by Janeway (4). Tracings of the oscillations of a column of air between the compressing band and the column of mercury in the manometer are obtained, but there is no graphic record of the height of the column of mercury by which the pressure may be estimated. It is, therefore, necessary to watch the manometer and note the oscillations. The return of the pulse at the wrist is found to coincide with the commencement of large oscillations, and there can be no difficulty, therefore, in the estimation of the systolic pressure; while, according to Erlanger, the point at which the large oscillations suddenly begin to diminish is an indication of the diastolic pressure. The author's observations with this instrument, which have been very numerous, lead him to concur with Erlanger in these views.

The sphygmomanometer recently introduced by the author (28) also takes advantage of the principle of circular compression in order to estimate the arterial

pressure. It has a mercurial manometer, the lumen of which is exactly that of the ordinary physiological kymograph. The air in the armlet can be increased, and the pressure on the limb elevated, by means of a large syringe, and the pressure may be raised quickly or slowly according to requirements. By means of a valve the pressure may also be lowered quickly or slowly. A float rests upon the mercury, surrounded, as in the physiological laboratory, by alcohol, and an upright rod of aluminium leads to a horizontal arm which writes on the revolving cylinder. In order to record the absolute zero, a fixed arm traces the abscissa upon the cylinder, which is driven by a clockwork placed horizontally. The pulsations of the artery below the point of compression are recorded by means of a transmission sphygmograph. This consists of a tambour brought into contact with the brachial or radial artery, as may be most convenient, by a pelotte resting upon the vessel. It is adjusted to the arm by means of a spring provided with a screw. This tambour is brought into communication by strong rubber tubing with another tambour, the movements of which are recorded on the cylinder simultaneously with the movements of the kymograph. The best tracing is obtained when the tambour in contact with the artery is larger than that connected with the recording lever, by means of which the movements are amplified. The whole apparatus is shown in Fig. 1.

In using the instrument, the pressure within the cuff may be raised gradually or quickly, the latter being the more usual course. If it is slowly raised, the tracing of the kymograph shows at first a line of ascent with small oscillations, but as it rises the pulsations become more and more marked, and the excursion of the index more extensive, until a maximum point of amplitude is attained, when they begin to diminish and gradually disappear. Simultaneously, the transmission sphygmograph records a gradual diminution in the amplitude of the pulsations, which finally cease. When all the movements of the kymograph, as well as of the sphygmo

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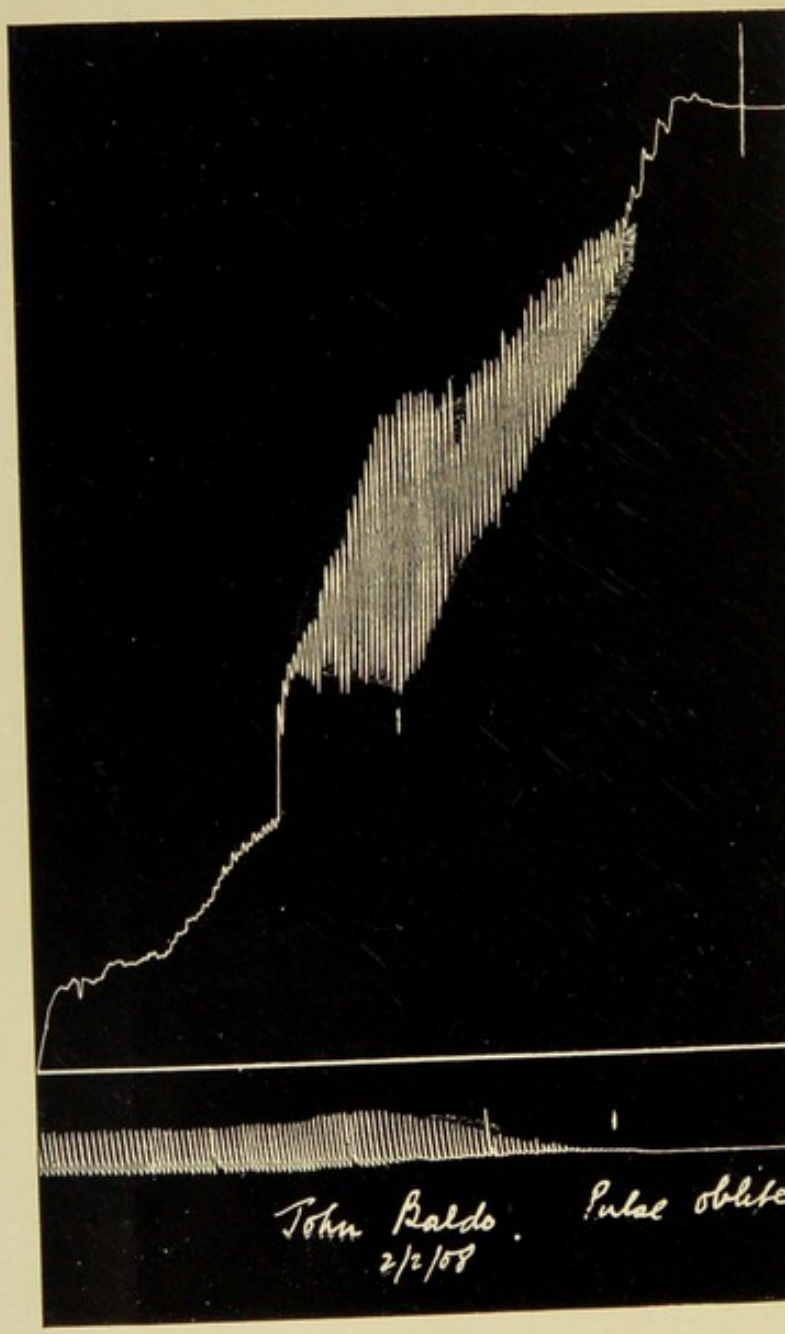

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graph, have come to an end, the pressure is allowed to fall by the escape of air from the valve, and the events which follow are the converse of those just described. Such a tracing is shown in Fig. 2. In this tracing the systolic pressure on the ascending curve, estimated by the disappearance of the pulsations of the transmission sphygmograph, was 180, and on the descending curve, measured by the reappearance of the pulsation, it was exactly the same. The diastolic pressure, estimated by the middle point of the greatest amplitude of pulsation on the ascending curve, was 120, while on the descending curve it was also the same. It will be observed that in this tracing there are great variations in the amplitude of the oscillations, both in the ascending and descending curves, but more especially on the curve of descent. These will require more careful consideration afterwards.

In the tracings the lowest curve is that given by the transmission sphygmograph. The abscissa is above it, and the kymographic tracing starts from this level. Since the manometer has a double column of mercury the height of the tracing above the abscissa must be doubled in estimating the pressure; if the tracing at any point should be 60 mm. from the abscissa, the pressure at that point must be read as 120 mm.Hg. As usually employed, the pressure is raised by one steady forcible expulsion of the air contained in the syringe until a high level is reached, 150 or 160 mm.Hg. being sufficient under ordinary circumstances. The valve, already set at the slow escape, allows the pressure to fall gradually. If sufficient pressure has been employed, the tracing from the artery, after a few oscillations, due to the inertia of the mercury, shows an entire absence of all movements, or only very small pulsations, and the curve resulting from the gradual lowering of the column of mercury is therefore almost destitute of any fluctuations. The instant that the arterial pressure overcomes the resistance, small waves begin to appear in the tracing given by the transmission sphygmograph.

Sometimes, as was indeed noticed by von Recklinghausen (29), Janeway (4), and Masing (30), in taking tracings either with the sphygmograph or plethysmograph along with the Riva Rocci sphygmomanometer, one or two little waves show themselves before the appearance of definite pulsation. In most cases, however, the return of the pulsation is quite unmistakable. The usual appearances are shown in Fig. 3, taken with slow revolution of the cylinder, and in Fig. 4 with quick movement.

In the interpretation of the tracings there is one point which may always be depended upon with a reasonable degree of certainty: the point at which the pulsation returns in the vessel below the seat of compression is approximately the systolic pressure. This has been admitted ever since the observations of Vierordt (11) and von Basch (14). The middle point of the kymographic curve at this point is therefore chosen as the index of systolic pressure. It is perfectly true that it is not absolutely the end pressure. The top of the first wave which appears gives the maximum systolic pressure indeed, but it is the lateral, and not the end pressure which is recorded, and therefore the method of circular compression, as was shown by Masing (30), is not the absolute maximum; the difference, however, between the lateral and terminal pressures in one of the larger arteries is inconsiderable.

The determination of the diastolic pressure is not such an easy problem. Marey (12) originally suggested that the point at which the largest swing of the instrument occurred was an index of the mean pressure, and this was adopted and amplified by Roy and Adami (31). It has been proved, however, by Howell and Brush (27) that this does not indicate the mean, but the diastolic pressure. Masing (30), who obtained some tracings from the artery below the seat of compression, believes that the greatest movement of the sphygmographic tracing marks the diastolic pressure. This must, however, be an error, as the greatest amplitude of oscillation of the sphygmographic curve is very commonly found after the pressure in the arm

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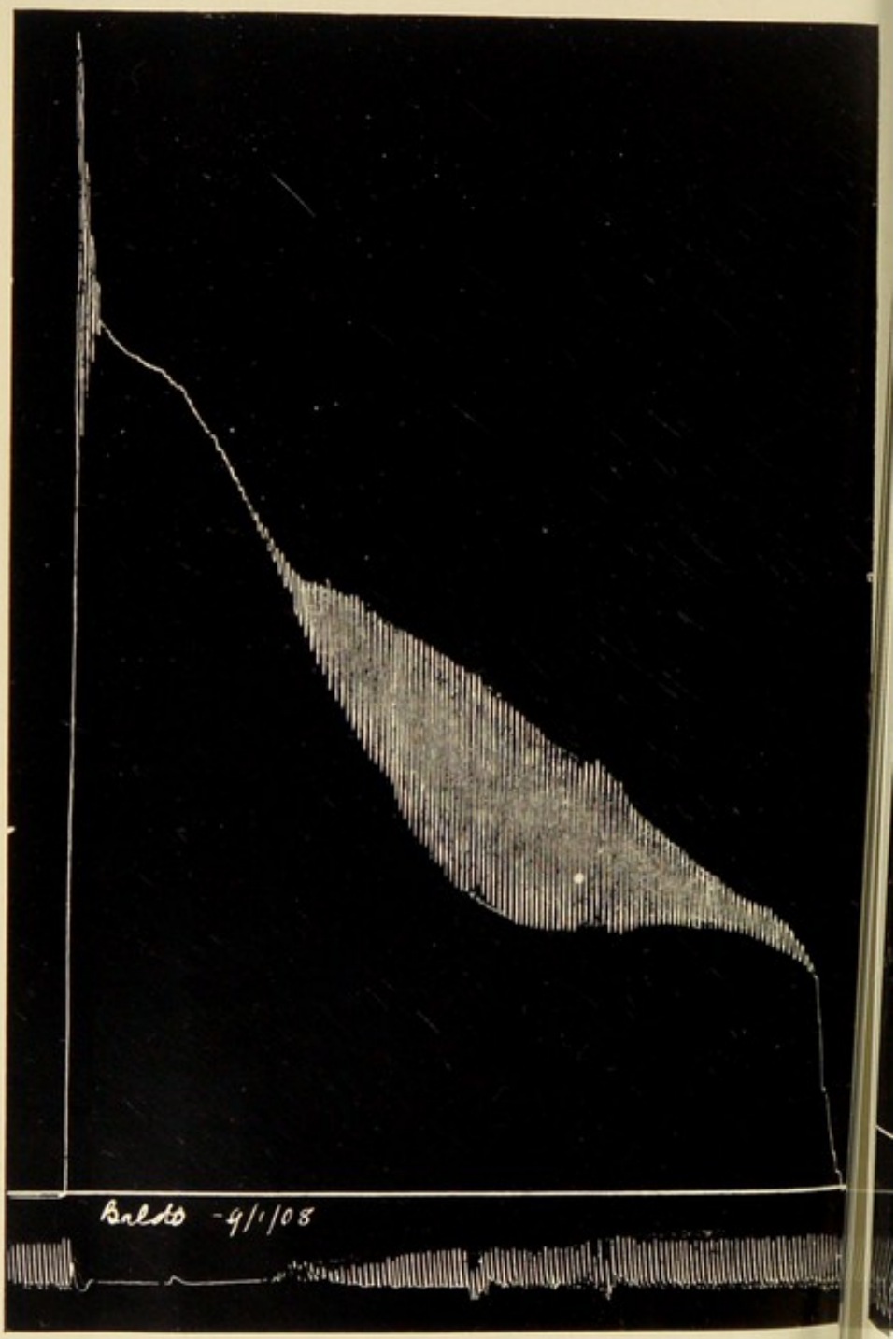
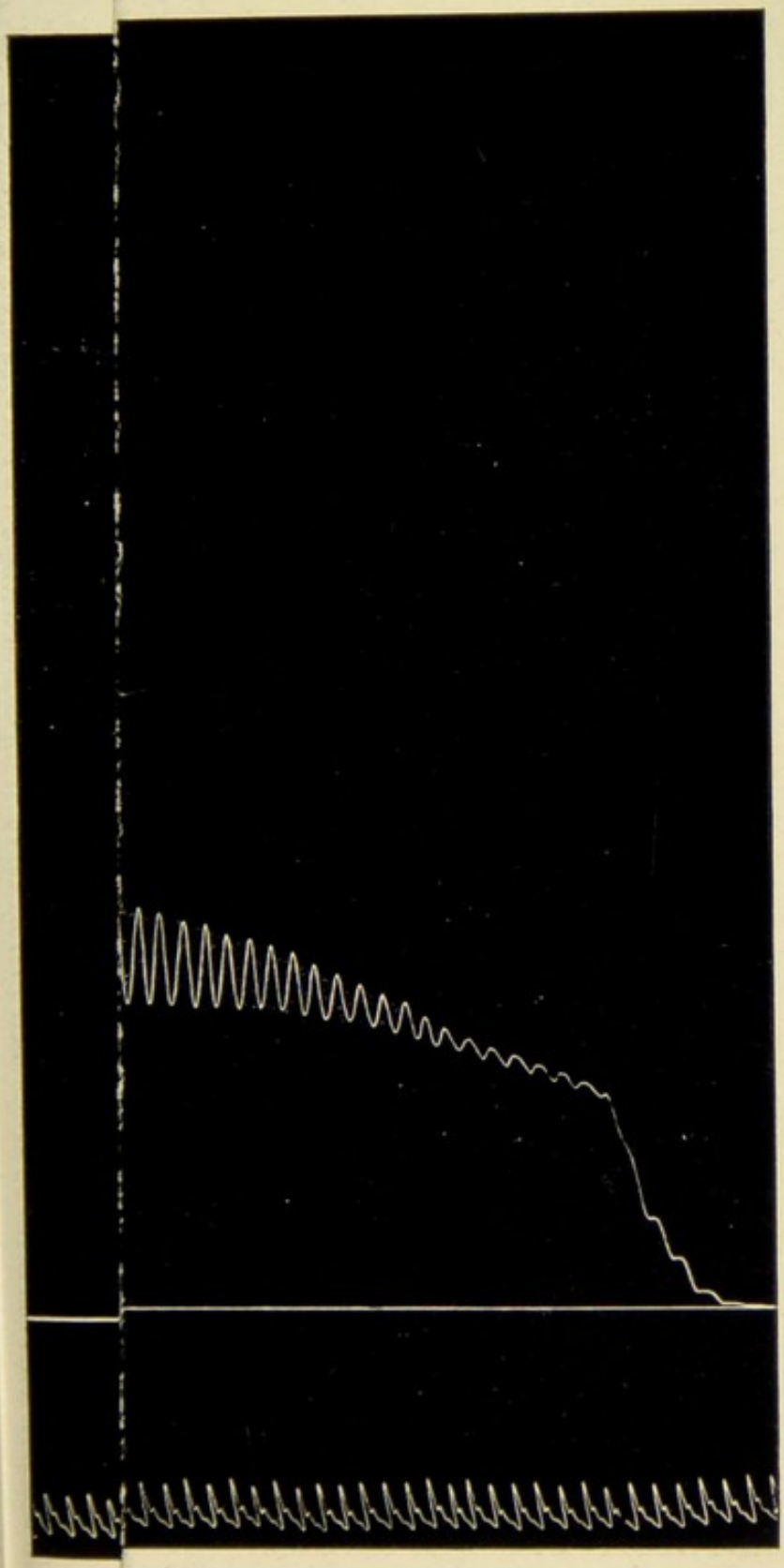


Dr G. A. Gibson, M.D., D.Sc., LL.D. Fig. 3.



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let has been allowed to fall nearly, if not quite, to zero, and the results obtained by this method of estimation are unmistakably erroneous. The author's method of obtaining the diastolic pressure is to ascertain where the greatest amplitude of oscillation occurs in the kymographic curve, and to take the middle point of this as the expression of the diastolic pressure.

In Fig. 3, for example, while the systolic pressure by every observer would be reckoned as 180 mm.Hg., the diastolic pressure as estimated by the author would be 110, and by the method of Masing 90 mm.Hg. In Fig. 4 the systolic pressure is 170 mm.Hg., and the diastolic by the author's computation 106, while according to Masing it would be 90. In some other tracings this is even more striking, as the maximum excursions of the transmission sphygmograph occur after the pressure in the armlet has been entirely removed. Fig. 3 is a good example of such a tracing.

At first the lowest point of the greatest swing seemed to the author that which might be considered as the index. There is one objection to this, however, which was suggested long ago by Marey (12), and which has been urged upon the author by Dr Janeway in private correspondence. He points out that if the pressure in the apparatus is allowed to fall continuously, the inertia of the mercury will be apt to carry the lowest point of oscillation below the true level. This has been carefully tested by arresting the escape for a few seconds, after each five or ten millimetres of descent. It has been observed that if the escape was recommenced at an instant when the curve was falling, the inertia sometimes caused the curve to fall as much as 10 mm. If, on the contrary, the pressure recommenced its escape during an ascent of the kymographic index, the result never exceeded 5 mm., and was usually 2 or 3 mm. There is, therefore, real weight in the criticism, and it has led the author to modify his first method. By taking the mean instead of the lowest point of the curve, the inertia is as far as possible compensated for.

Fig. 5 is a curve obtained by the method of intermittent escape, and illustrates this point quite distinctly.

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REPORT BY COMMITTEE.

The undersigned members of your Committee have carefully studied both the construction and the practical working of the Sphygmomanometer devised by Dr G. A. Gibson, and find:—

1. The instrument, though based on the essential principles of the Erlanger and Riva-Rocci types, possesses very distinct advantages over either form.

2. Like the Riva-Rocci it ascertains the force of systolic pressure, and like the Erlanger both the systolic and the diastolic.

3. The very valuable modification which renders this instrument, in our opinion, superior to the existing types, is the method of recording by means of the Ludwig manometer the exact pressure of the air in the armlet. The tracing is superposed over the sphygmographic record, and we are thus enabled to ascertain the exact value of the systolic pressure in terms of millimetres of mercury.

4. The recording apparatus is very simple in character, and the instrument is easily understood and worked.

5. The instrument should prove of great service in clinical observation.

The members would very heartily commend this Paper to the notice of the Prize Committee.

Dawson Turner, *Convener.*
James A. Russell.
David A. Farquharson.