

## Short Articles

### PHYSIOLOGICAL APPARATUS IN THE WELLCOME MUSEUM 2. THE DUDGEON SPHYGMOGRAPH AND ITS DESCENDANTS

by

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THE FIRST convenient sphygmograph that recorded the pulse curve without the need to break the skin was produced by E. J. Marey in 1860.<sup>1</sup> In Britain it was soon taken up by the young men who were to found the science of experimental physiology.<sup>2</sup> Clinicians in general ignored the instrument, preferring their own traditional digital discrimination of the varieties of the pulse. With some notable exceptions this remained true until the sphygmograph was finally eclipsed by techniques such as electrocardiography.

The Marey instrument was in fact rather cumbersome and physicians soon introduced modifications and eventually devised new instruments altogether. One method which had also originated from Marey was to use a tambour rather than a lever, to produce a transmission rather than a direct sphygmograph (Fig. 1).<sup>3</sup> By attaching a microphone to the sphygmograph invented by Pond, Benjamin Ward Richardson rendered the pulse audible.<sup>4</sup> The most significant development, however, was the invention of a new compact sphygmograph by Robert Ellis Dudgeon (Fig. 2).<sup>5</sup> He was born in 1820 and obtained his M.D. at Edinburgh, though he soon left more orthodox medicine to become a homeopath. He edited the *British Journal of Homeopathy* and served on the staff of the London Homeopathic Hospital. His inventiveness was not confined to the sphygmograph, for he also devised a pair of spectacles for

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<sup>1</sup> Christopher Lawrence, 'Physiological apparatus in the Wellcome Museum: 1. The Marey sphygmograph', *Med. Hist.*, 1978, 22: 196–200.

<sup>2</sup> A series of brilliant physiological experiments were performed with the instrument by Alfred Henry Garrod. I hope to publish an account of them shortly.

<sup>3</sup> An even simpler form of transmission sphygmograph was described by W. J. Fleming, lecturer on physiology at the Glasgow Royal Infirmary. See 'A simple form of transmission sphygmograph', *J. Anat. Physiol.*, 1877–78, 12: 144–146. The sphygmograph figured here is little more than a tambour on a stand.

<sup>4</sup> Pond was probably Erasmus A. Pond of Vermont. See *Pond's perfected sphygmograph*, Michigan, Parke, Davis, [n.d.]; Benjamin Ward Richardson, 'Note on the invention of a method for making the movements of the pulse audible by telephone. The sphygmophone', *Proc. Roy. Soc.*, 1879, 39: 70; and 'The sphygmophone and pulse stethoscope', *Asclepiad*, 1886, 3: 338–339. David Edward Hughes had described the first microphone only a year earlier than Richardson's application of it. (D. E. Hughes, 'On the action of sonorous vibrations in varying the force of an electric current', *Proc. Roy. Soc.*, 1878, 27: 362–369.) On Hughes see *New Scientist*, 11 May 1978, pp. 378–379.

<sup>5</sup> R. E. Dudgeon, *The sphygmograph*, London, Bailliere, Tindall & Cox, 1882.

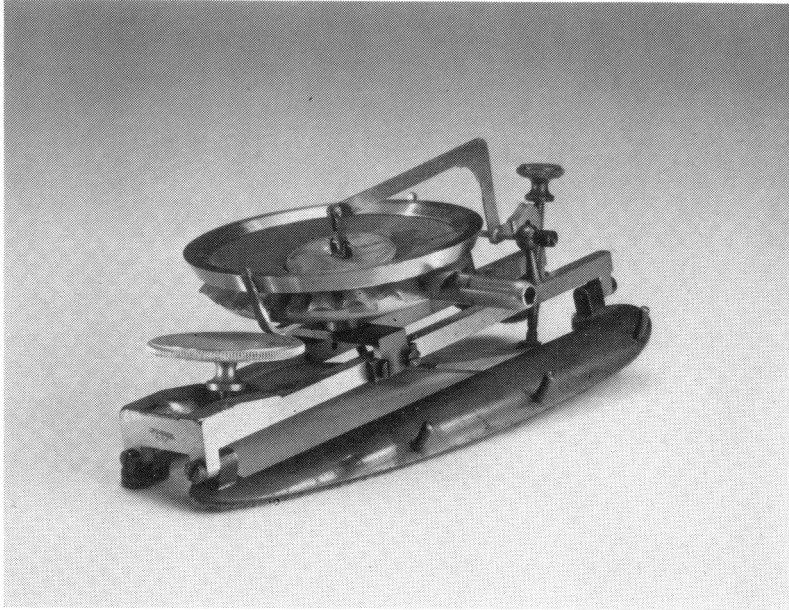


Figure 1.  
A transmission sphygmograph. See Appendix B. Instrument I. (*Crown copyright.*)

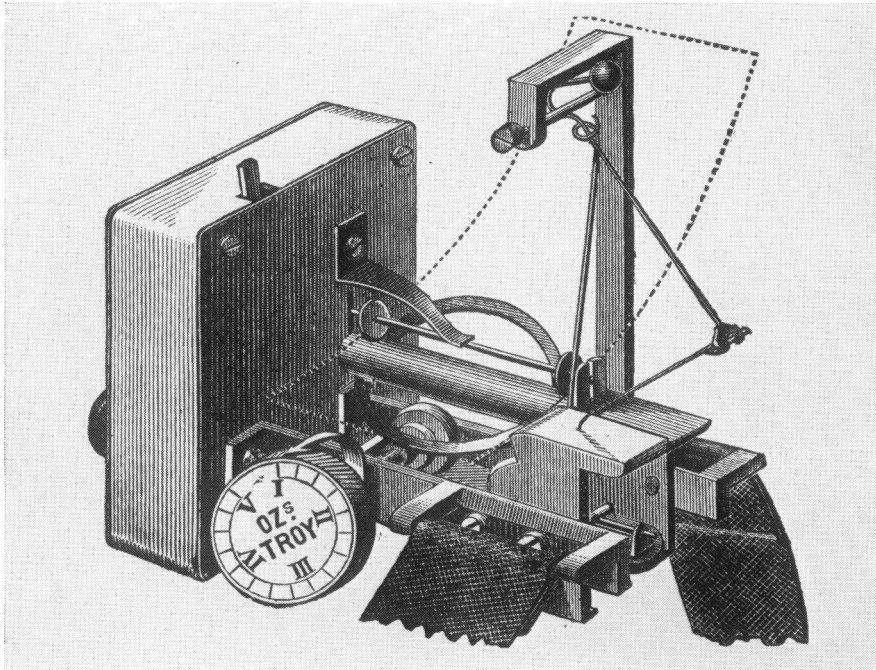


Figure 2.  
A Dudgeon sphygmograph. From L. Landois, *A textbook of human physiology*, translated by William Stirling, 4th ed., London, Charles Griffin, 1885, vol. 1, p. 131. (*By courtesy of the Wellcome Trustees.*)

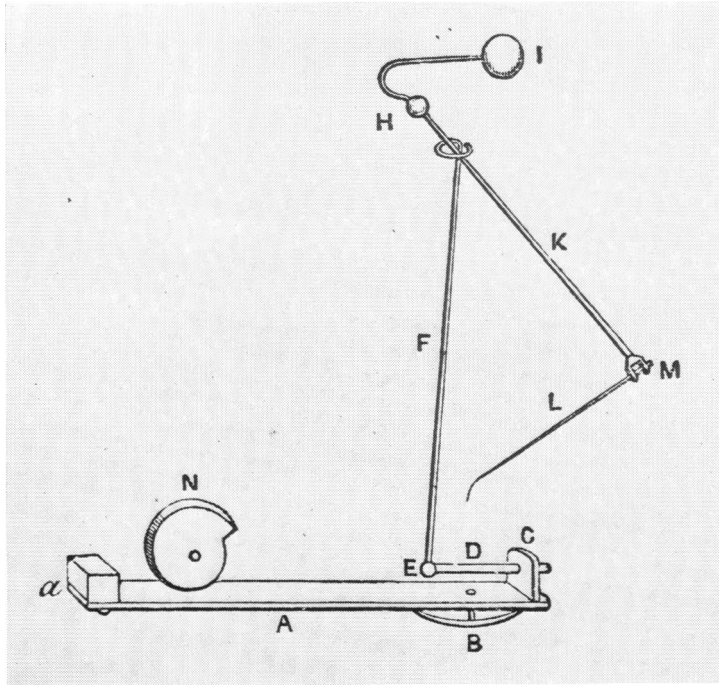


Figure 3.  
Schematic representation of the mechanism of a Dudgeon sphygmograph.  
From R. E. Dudgeon, *The sphygmograph*, London, Bailliere, Tindall &  
Cox, 1882, fig. 2. (By courtesy of the Wellcome Trustees.)

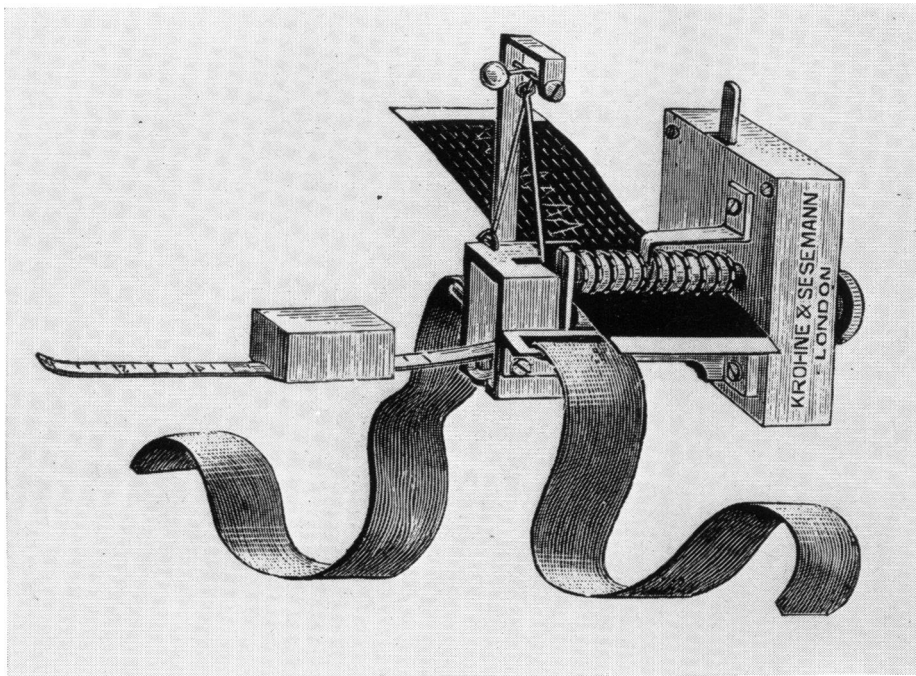


Figure 4.  
Richardson's original illustration of his sphygmograph. From Benjamin Ward Richardson,  
'Standard pulse readings', *Asclepiad*, 1885 2: 194. (By courtesy of the Wellcome Trustees.)

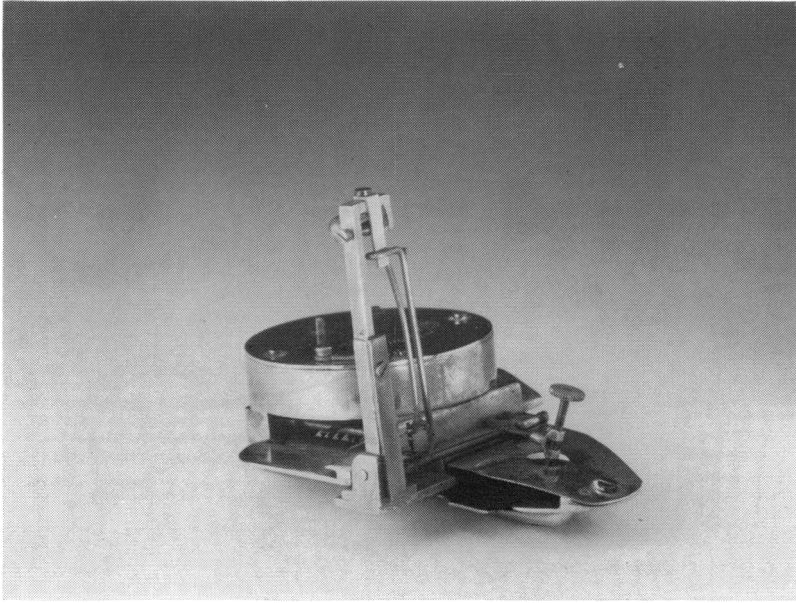


Figure 5.  
A sphygmograph designed by Mortimer Granville. See Appendix A. Instrument V.  
(Crown copyright.)

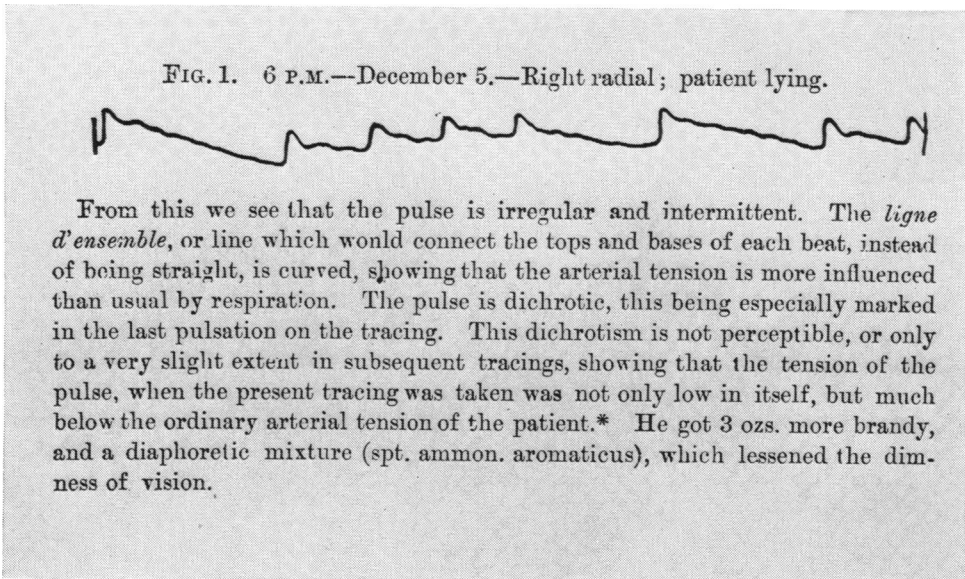


Figure 6.  
The pulse in a case of digitalis poisoning recorded by Lauder Brunton. From Sir Lauder Brunton, *Collected papers on circulation and respiration*, London, Macmillan, 1907, p. 100. (By courtesy of the Wellcome Trustees.)

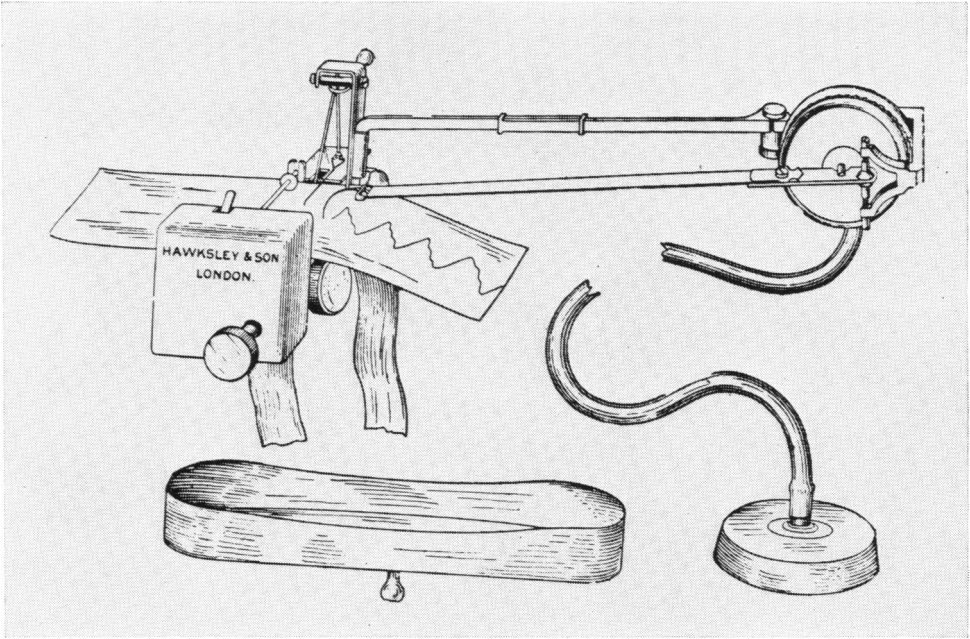


Figure 7.  
Mackenzie's clinical polygraph. From James Mackenzie, *Diseases of the heart*, 4th ed., London, Oxford University Press, 1925, p. 420. (By courtesy of the Wellcome Trustees.)

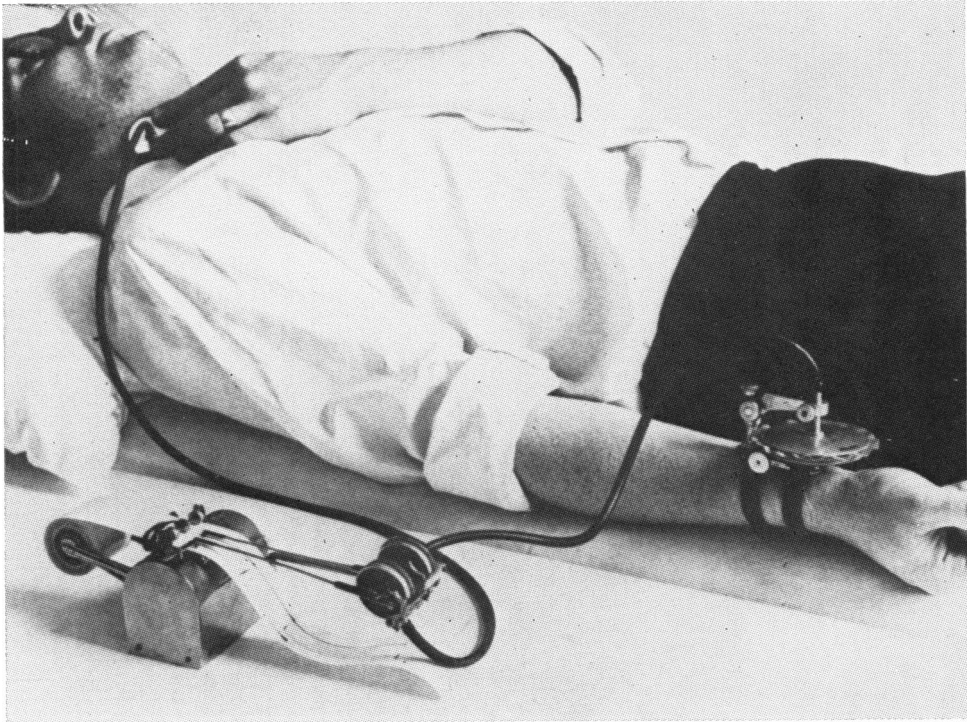


Figure 8.  
Mackenzie's original ink polygraph. See Appendix C. Instrument III. (By courtesy of the Wellcome Trustees.)

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use under water. He died in 1904. Dudgeon exhibited his sphygmograph in 1881 and published an account of it the following year. Its great advantage was its convenience: it was “two and a half by two inches; weight four ounces. When packed in its leather case it can easily be carried in the pocket.”<sup>6</sup>

Dudgeon’s instrument, like Marey’s, was of the direct type (Fig. 3). The rounded button B transmits the pulse wave through the stem, F, at the top of which is a loop in which lies a counterpoised rod, K, to the lower end of which the needle, L, is attached, the point of which describes the curve on smoked paper. This arrangement substituted a light compound lever with a gravity action pen for the simple lever and side writing pen of Marey. The result was that the shorter lighter pen arm had a higher frequency of vibration for the same magnification, and the lever, since it writes on a horizontal surface, inscribes the rise and fall of the pulse without an arc. Dudgeon took from Mahomed the idea of an eccentric, N, for altering the pressure applied to the artery.

The Dudgeon soon became the most popular instrument in Britain, rapidly displacing the Marey type. The Wellcome Museum\*\* contains twelve instruments of the original Dudgeon variety (see Appendix A). It was figured in most instrument catalogues and the major physiological texts of the late nineteenth century.<sup>7</sup> Its popularity, of course, coincided with the rapid growth of experimental physiology. Like the Marey instrument before, it soon became the focus of innovation, the most significant of which was that of Benjamin Ward Richardson.<sup>8</sup> Richardson’s variation consisted essentially of removing the eccentric pressure gauge and replacing it with a steel-yard balance which projected as a weighing bar from the fore part of the instrument. Richardson considered this innovation produced easy and accurately readable measure of pressure change. His other modification was to serrate the smooth rod that carried the carbonized paper, thus producing at the same time as the pulse curves a series of vertical and horizontal lines on the recording (Fig. 4). In effect then, he produced a scale permitting accurate measurement of the tracings. Not all models possess this serrated rod (see Appendix A).

Richardson’s model soon joined Dudgeon’s as the most popular in Britain, as a survey of instrument catalogues demonstrates. Their success did not deter innovators from devising detailed modifications of these instruments, such as new methods of regulating the pressure or different time markers.<sup>9</sup> The only other radical modification produced in Britain was a new design by Mortimer Granville. Born in 1833, Granville was a Member of the Royal College of Physicians of London, a contributor to the editorial columns of the *Lancet*, and an author of several treatises on “nervous disorders”. He died in 1900.<sup>10</sup> Granville’s sphygmograph was of the direct type, the

\*\*The Museum of the Wellcome Institute for the History of Medicine is currently being transferred to the Science Museum, South Kensington, London, on indefinite loan, where it will form the Wellcome Museum of the History of Medicine.

<sup>6</sup> *Ibid.*, p. 29.

<sup>7</sup> See for example L. Landois, *A textbook of human physiology*, translated by William Stirling, 4th ed., London, Charles Griffin, 1885, vol. 1, p. 131.

<sup>8</sup> Benjamin Ward Richardson, ‘Standard pulse readings’, *Asclepiad*, 1885, 2: 193–203.

<sup>9</sup> J. Fletcher Little, ‘Improved Richardson’s sphygmograph’, *Lancet*, 1903, i: 247; and L. N. Hesketh Biggs, ‘Time marker attachment for Dudgeon sphygmograph’, *ibid.*, 1908, i: 797.

<sup>10</sup> Obituary, *Br. med. J.*, 1900, ii: 1619.

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compactness of his instrument was obtained by using Dudgeon's transmission mechanism and hinging it to lie flat when not in use. It also incorporated a set of teeth for marking a scale on the paper (Fig. 5).

Like the Marey instrument before them, the sphygmographs of Dudgeon and Richardson soon became part of the physiologist's arsenal. Thomas Lewis, who himself devised a balancing adjustment for the Dudgeon instrument, recommended it for its "considerable delicacy and accuracy".<sup>11</sup> Some of Lewis's very first cardiological investigations were on the nature of the sphygmographic trace.<sup>12</sup> The instruments, however, still failed to make a significant impression on clinical practitioners. Sir William Broadbent in his manual *The pulse* remarked of the sphygmograph "the readings of its tracings can only be safely undertaken by one conversant with the use of the sphygmograph and the vagaries thereof, and if any special result is expected or wished for, an enthusiastic investigator can obtain it and may, without the least conscious intention, twist facts in the desired direction."<sup>13</sup> Physicians were taught to eschew instrumental aids and educate the "finger".<sup>14</sup>

There were, however, a few physicians who used the sphygmograph as a major research tool in clinical medicine. F. A. Mahomed used the Marey sphygmograph soon after its invention, but his career was tragically cut short at the age of thirty-three in 1884. I have described Mahomed's researches in an earlier paper.<sup>15</sup> Thomas Lauder Brunton also used the Marey sphygmograph in its early days and later the other models that became available. Sir James Mackenzie's cardiological investigations were performed at the end of the century, by which time the Dudgeon had become the most popular instrument. The Wellcome Museum contains a large collection of medical and physiological instruments associated with Lauder Brunton and several important items presented by Lady Mackenzie (see Appendices).

Thomas Lauder Brunton was born in 1844 and died in 1916. A major figure in late nineteenth-century British medicine, curiously he has failed to attract a biographer. He graduated M.D. at Edinburgh in 1868, and went on to spend two years in continental laboratories including Ludwig's at Leipzig. He returned to London and for the rest of his career was associated with St. Bartholomew's Hospital.<sup>16</sup> Brunton began his career in experimental medicine with his thesis in which he investigated the action of digitalis.<sup>17</sup> The work consisted of observations of the effect

<sup>11</sup> Thomas Lewis, 'The interpretation of sphygmograph tracings, and of tracings produced by compressing the brachial artery', *Practitioner*, 1907, 39: 207.

<sup>12</sup> Thomas Lewis, 'The interpretation of the primary and first secondary wave in sphygmograph tracings', *J. Anat. Physiol.*, 1907, 41: 137-140.

<sup>13</sup> W. H. Broadbent, *The pulse*, London Cassell, 1890, p. 33. Broadbent's 300-page book was intended "to describe the variations in character of the pulse as they are felt by the finger" (p. 32). He did not object to the instrument in research, only in clinical practice. Interestingly, he preferred the original Marey to the Dudgeon for he thought there existed in the latter a "gratuitous provision for exaggerations" (p. 33).

<sup>14</sup> Graham Steell, *The use of the sphygmograph in clinical medicine*, Manchester, Sherratt & Hughes, 1899, p. 5. For similar comments see J. L. Waters, 'Some remarks anent the sphygmograph', *Caled. med. J.*, 1894-96, 2: 166-173.

<sup>15</sup> Lawrence, op. cit., note 1 above.

<sup>16</sup> Obituary, *Br. med. J.*, 1916, ii: 440.

<sup>17</sup> 'On digitalis, with some observations on the urine', Edinburgh University Thesis, 1866—conveniently found in Sir Lauder Brunton, *Collected papers on circulation and respiration*, London, Macmillan, 1907, pp. 29-136.

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of the drug on his own urine output and urinary constituents under carefully controlled conditions. He discovered little effect with normal doses but marked diuresis at levels approaching poisoning. He took various sphygmographic traces of his pulse and also made recordings in a case of digitalis poisoning (Fig. 6).<sup>18</sup> In the Lauder Brunton collection at the Wellcome Museum of the History of Medicine is a transmission instrument of the Marey type; it was possibly this device Brunton used rather than the more common direct variety (Fig. 1). Brunton's most famous investigations, however, were performed whilst still a houseman at the Edinburgh Royal Infirmary.<sup>19</sup> On the evidence of one patient with resting angina, plus others apparently confirming his views, Brunton believed the pain to be caused by transient hypertension, and speculated that amyl nitrite, a known vasodilator, would reduce the blood pressure and thus relieve the symptom. He took sphygmographic traces of patients with angina before and after inhalation of the drug and demonstrated a reduced pulse rate and diminished tension associated with symptomatic relief. Brunton did not, however, give details of his patients or reproduce the tracings on which his inferences were based. It is hard at first to see why on experimental evidence as opposed to theory Brunton thought angina to be due to transient hypertension, for his tracings could show the *fall* in blood pressure amyl nitrite produces but not typically a rise associated with the attack. Angina is usually caused by ischaemia resulting from coronary artery disease, and is not correlated with a hypertensive episode. In 1870 Brunton described in detail one of the patients he had examined in 1866.<sup>20</sup> He was a twenty-six-year-old blacksmith with severe rheumatic aortic valve disease. He was clearly the principal patient on whom Brunton had performed his researches, for he had severe resting angina relieved by amyl nitrite and his sphygmographic traces showed a raised blood pressure associated with the episodes. Aortic regurgitation may in fact be the origin of severe resting angina, during which the blood pressure rises, often even before the attack begins. Such patients, of course, may well not have coronary artery disease. It was certainly the experience derived from this case which encouraged Brunton in his belief that angina followed transient hypertension.

In his later career Brunton turned his attention to the digestive tract and pharmacology. During the 1870s and 1880s, however, he continued to publish papers on cardiovascular and respiratory physiology and pathology. His personal collection of instruments contains sphygmographs of several different types dating from these years (see Appendix B).

Sir James Mackenzie (1853–1925) is probably the most famous person associated with the non-invasive instrumental investigation of normal and pathological cardiovascular phenomena. Much of his important clinical work was done whilst a general practitioner in Burnley; later he became director of an institute for clinical research at St. Andrews University. Unlike Brunton he has appealed to biographers, who

<sup>18</sup> *Ibid.*, pp. 99–103.

<sup>19</sup> T. Lauder Brunton, 'On the use of nitrite of amyl in angina pectoris', *Lancet*, 1867, ii: 97; or in Brunton, *op. cit.*, note 17 above, pp. 137–139.

<sup>20</sup> Thomas Lauder Brunton, 'On nitrite of amyl in angina pectoris', *Clin. Soc. Rep.*, 1870, 3: or in Brunton, *op. cit.*, note 17 above, pp. 185–196.



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may be turned to for details of his life.<sup>21</sup> Most earlier workers both in physiology and clinical medicine had directed their attention to the rate of the pulse, the force of the heartbeat, and consequently the shape and amplitude of the sphygmographic tracing. Mackenzie was one of the first workers to be interested in the regularity or otherwise of the pulse. This interest resulted eventually in the identification of auricular fibrillation and the ventricular extrasystole. He also laid the foundation of the modern concept of heart failure. Mackenzie's earliest investigations employed the Dudgeon sphygmograph which he found "the handiest and the most useful".<sup>22</sup> To elucidate further the heart's action, Mackenzie in the 1890s turned his attention to the jugular venous pulse; his solution to the problem of recording both the venous pulse and the arterial cycle simultaneously was the clinical polygraph (Fig. 7). "This method consists in placing a hollow lead cone or funnel over any pulsating part where the surface of the skin permits the cavity of the funnel to be hermetically closed . . . this receiver is connected by means of an india rubber tube to a Marey's tambour and lever the latter of which can be made to write on the smoked paper of a Dudgeon's sphygmograph."<sup>23</sup> Mackenzie found that the polygraph was "not convenient when movements had to be recorded over long periods".<sup>24</sup> The result was the famous ink polygraph which allowed a pen to write on a roll of paper as it was being unwound (Fig. 8). The Wellcome Collection contains Mackenzie's sphygmograph, tambour, and original ink polygraph (Appendix C).

The sphygmograph entered British medicine as one of the tools of experimental physiology, in which field it still survives. The reasons for its failure to make much headway in clinical practice were related to the concept of the medical art held by most practitioners and the demands of the instrument itself: it was, in short, difficult to handle.<sup>25</sup> By the 1880s, with the invention of non-invasive manometry, its use as an instrument for estimating blood pressure disappeared. In the early years of this century electrocardiography usurped almost all its other functions. Sphygmography was a technique transitional between two views of medicine, one based on anatomy and the clinical art and the other on experimental investigation. In the hands of a few sophisticated practitioners it demonstrated unequivocally the particular explanatory power of the latter, and, no doubt, facilitated its triumph.

#### APPENDIX A

- I. Dudgeon sphygmograph. Dudgeon's original model made by J. Ganter, London. Complete and in good condition. A600283.
- II. An instrument of the Dudgeon type but larger and heavier, with the pressure adjuster attached to the back of the motor. In good condition though motor not

<sup>21</sup> R. MacNair Wilson, *The beloved physician: Sir James Mackenzie*, London, John Murray, 1926. Alex Mair, *Sir James Mackenzie M.D. 1853-1925, general practitioner*, Edinburgh, Churchill Livingstone, 1973.

<sup>22</sup> James Mackenzie, *The study of the pulse*, Edinburgh, Young J. Pentland, 1902, p. 8.

<sup>23</sup> Quoted in Mair, *op. cit.*, note 21 above, p. 90.

<sup>24</sup> James Mackenzie, *Diseases of the heart*, 4th ed., London, Oxford University Press, 1925, p. 421.

<sup>25</sup> For accounts of the two sorts of medicine see Gerald Lynn Geison, *Sir Michael Foster and the rise of the Cambridge School of Physiology 1870-1900*, Princeton University Press, 1978; and Richard D. French, *Antivivisection and medical science in Victorian society*, Princeton University Press, 1975.

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- working. Made by G. Boullitte of Paris. No date but probably late nineteenth century. A600386.
- III. Richardson sphygmograph. Has steelyard and toothed roller, motor not working. No maker's name. A600281.
- IV. Richardson sphygmograph, without toothed roller. In working order. Made by J. Richardson & Co., Leicester. A600374.
- V. Sphygmograph designed by Mortimer Granville. Made by Walters & Co., London. The moving parts are stiff and the motor not working. A600376. See Fig. 5.

### APPENDIX B PULSE-REGISTERING INSTRUMENTS BELONGING TO THOMAS LAUDER BRUNTON

- I. Transmission sphygmograph. Designed by E. J. Marey. Made by C. Verdin, Paris. No tubing or recording apparatus but in good condition. A600282. See Fig. 1.
- II. Direct sphygmograph. Similar to the model described by von Frey.<sup>26</sup> Made by Petzhold of Leipzig, it may date from Brunton's stay with Ludwig, in which case it antedates von Frey's model. Lacks motor and carriage. A600368.
- III. Dudgeon sphygmograph in excellent working order. No maker's name. A600369.

### APPENDIX C PULSE-REGISTERING APPARATUS BELONGING TO SIR JAMES MACKENZIE

- I. Dudgeon sphygmograph in excellent working order. Made by Gardner & Son, Edinburgh. A56269.
- II. Tambour, made of lead with a parchment skin. A56266.
- III. Mackenzie's original ink polygraph.<sup>27</sup> Consists of a receiver for application to the jugular pulse; a wrist tambour, which lacks the small knob which transmits the impulse from the spring; transmission tubing and tambour attached to recording arms. The case contains separate clockwork for the roller and the time marking pens. The key for the latter is broken, otherwise complete. No maker's name. A55288. See Fig. 8.

<sup>26</sup> Max von Frey, *Die Untersuchung des Pulses*, Berlin, Springer, 1892.

<sup>27</sup> For a full description see Mackenzie, *op. cit.*, note 24 above, p. 422.