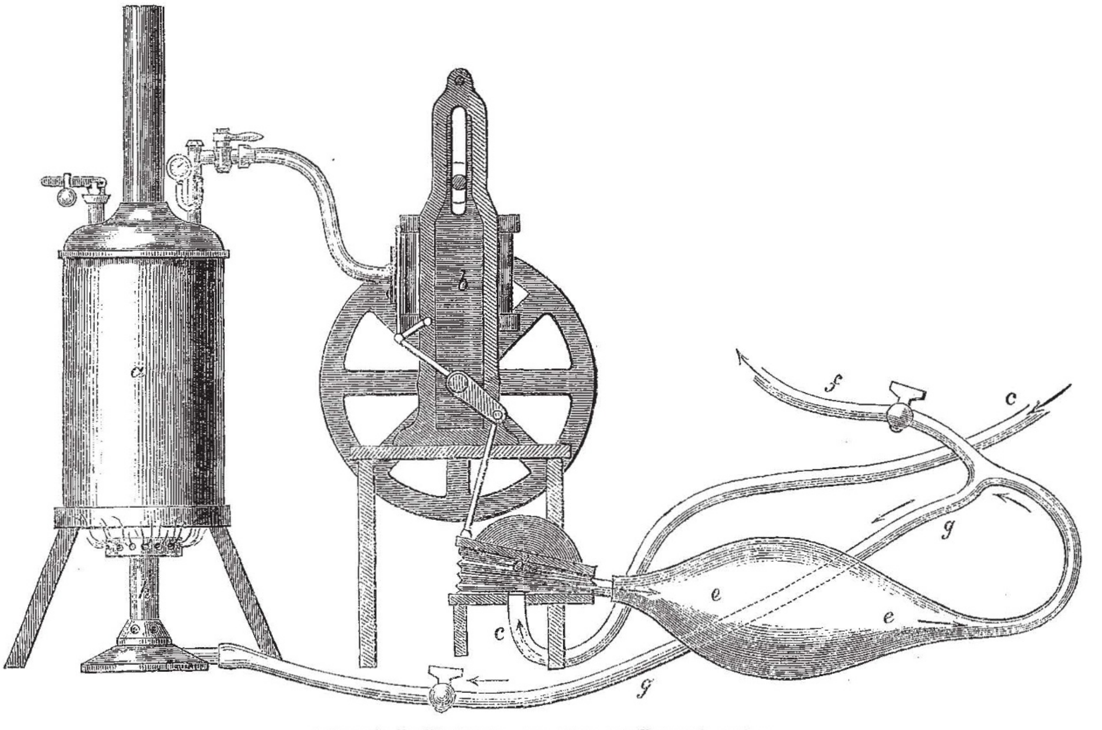
THE HEART AND THE SPHYGMOGRAPH*

IN the same way that by the spectroscope much can be learned as to the chemical constitution and the physical changes going on in the sun, so by the sphygmograph applied to the artery at the wrist many of the most important phenomena occurring in the heart can be studied with a facility that cannot be otherwise attained. Till the introduction of the sphygmograph of Marey the pulse was considered to be little more than a simple up and down movement, because the instruments employed to register it, such as those of Herisson, Ludwig, and Vierordt, developed so much momentum that the details of the true trace were disguised. In the instrument as at present employed, the substitution of counterbalancing springs instead of weights has so far improved its efficiency, that the pulse is now known to form a decidedly complicated curve if its movements are allowed to record themselves on a moving paper. The sphygmograph trace, as thus produced, gives indications in two directions; first, as to the action of the valves of the heart; and secondly, as to the manner in which the muscular walls of the ventricles perform their work. It is to the former of these subjects that most physiologists have directed their observations in employing the instrument; but it is to the latter, the more important of the two, that it is my intention to direct attention on the present occasion.

The heart being nothing more than a pump of a peculiar construction, much may be learned by comparing it with other artificially constructed machines for the same purpose. In most such machines the force which keeps the pump at work is constant in power, in other words it does not vary automatically in efficiency with the amount of work that is expected of it. In the locomotive engine, however, there is an arrangement by which the furnace becomes hotter as the speed at which it moves is increased, the waste steam pipe opening into the funnel and so varying the amount of the draught through the boiler tubes. With this arrangement it is nevertheless evident that there is a great waste of fuel in the construction of the furnace.



Automatically Working-engine, when supplied with coal-gas.

It is quite possible to construct a steam-engine on much more economical principles, and the accompanying figure illustrates the manner in which the small engine on the table is at present working (see Figure). The boiler (*a*) being sufficiently heated, drives the engine (*b*), which performs work by pumping *coal-gas* from the tube *c* through the pump *d*, into the elastic reservoir *e*. From this elastic bag most of the coal-gas escapes, through the tube *f*, into an ordinary gas bag, but a tube (*g*) carries some of it to supply the Bunsen's burner (*h*) which heats the boiler. It is evident that with this arrangement the size of the flame of the Bunsen's burner (*h*), and therefore the pressure of steam in the boiler, which is the same as saying the efficiency of the engine, varies with the amount of work required of that engine; for the greater the pressure in the elastic bag, the harder is it for the engine to perform the work required of it, and the greater is the burner-flame. With a certain proportion between the sizes of the orifices of the taps and the extensibility of the elastic bag and tubes, it would be possible to arrange this engine in such a manner that, within certain limits, the velocity of the fly-wheel would not vary with the pressure in the elastic bag; in other words, with the work to be done. That the heart is a pump constructed on the same principle as this engine is the teaching of the sphygmograph, as far as it is in my power to interpret its curves, the proof resting on the following considerations.

First, the analogy between the anatomical distribution of the arteries and the different parts in connection with the engine is not difficult to trace. The coal-gas corresponds to the blood, the boiler (*a*) together with the engine (*b*) to the muscular tissue of the heart, whose left ventricular

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* Abstract of a lecture delivered by Mr. A. H. Garrod at the Royal Institution on the evening of Friday, Feb. 6.

cavity has its analogue in that of the bellows (*d*). The elastic reservoir, together with the tubes, corresponds to the systemic arteries, the gas-bag connected with the tube *f* (the capillaries) to the systemic veins; and the tube *g* to the coronary arteries, which supply the muscular tissue of the heart with nutrient blood, just as it does the boiler by means of the burner *h*. This, however, does not show that the pumping power of the heart varies directly as the blood-pressure; that such is the case depends on the opportunity offered by the sphygmograph-trace for the estimation of the length of the ventricular systole under different circumstances. Each beat or revotion of the heart is divided into two main parts—(1) the period of contraction or systole, and (2) the period of repose or diastole. The former of these occupies the interval between the commencement of the primary rise and that of the dicrotic rise in the sphygmograph trace; the latter from the dicrotic rise to the commencement of the succeeding primary rise. In all good tracings from healthy pulses these two points, the primary and dicrotic rises, are readily found; and their relative lengths can be estimated with great accuracy. A large number of measurements have enabled me to prove that *the relative lengths of the systolic and diastolic portions of the pulse-trace do not vary for any given pulse-rate.* But, as will be granted by most physiologists who have worked at the subject, *the blood-pressure in the arteries is quite independent of the pulse-rate.* Consequently the heart may be doing very different amounts of work without any variation in the pulse-rate, which is the same thing as saying, with the same length of systole; which makes it evident that, as in the above-described engine, *the force of the cardiac muscular contraction varies directly as the blood-pressure*, knowing what we do about the flow of fluids through capillary tubes, and the capacity of the arterial system under different degrees of blood-pressure.

The sphygmograph trace tells us more than this. Though the length of the systolic portion of the beat does not change with any given pulse-rate, nevertheless it does so greatly with different rapidities of pulse; my observations showing that the length of the systole varies as the cube root of the whole beat, being found from the equation $xy' = 47 \sqrt[3]{x}$ when $x =$ the pulse-rate and $y' =$ the ratio borne by the systole to the whole beat. From this no other inference can be drawn than that the length of the diastole, or period of cardiac rest, during which fresh blood is circulating through the ventricular walls, must modify the contractile force of its muscular substance. The exact extent of this influence can be more readily estimated by a study of the cardiograph trace, which is obtained by applying the sphygmograph to the side of the chest at any spot where the pulsations of the heart are to be felt. It may, from the thus obtained curves, be demonstrated that if not exactly, approximately, at least, *the nutrition of the heart's walls must vary as the square-root of the length of the diastolic period.*[*]

There is much, therefore, as I hope I have been able to show, to be learned respecting the action of the heart from measurement of sphygmograph tracings, and it is scarcely too bold to extend the generalisation to the properties of muscular tissue generally; for the fact that each beat depends entirely for its efficiency on the peculiarities in the blood-pressure and the duration of the previous diastole, removes all complications as to incompleteness of exhaustion, and all doubts as to the exact amount of work done by the muscular fibres themselves of that most perfect of engines, whose extreme perfection enables it to complete in most of us something like 750,000 beats in a week, and nearly thirty thousand million revolutions in a person by the time he is seventy years of age.

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[*] *Journal of Anatomy and Physiology*, May and November, 1873.

DR. VON MIKLUCHO MACLAY'S RESEARCHES AMONG THE PAPUANS[*]

WHEN lately at Buitenrovg—the scarcely euphonious equivalent of the "Sans Souci" of a former English Governor of Java—we had the good fortune to make the acquaintance of the owner of a name, whose peculiarity, no less than fame, has rendered it familiar to every biologist.

The friends—and we are sure they must be numerous—of Dr. Miklucho Maclay will regret to hear that he is determined, in spite of an aguish fever which still clings to him, and of, it is feared, some serious implication of the liver, to start again in a few days for the scene of his recent labours—the east coast of New Guinea, where he had previously spent fifteen months in close intercourse with the natives.

On September 19, 1871, the Russian corvette *Vitias* cast anchor in Astrolabe Gulf, and Dr. Maclay landed with two servants, one a Polynesian, the other a Swede. After a hut of very modest dimensions[†] had been built for him by the ship's carpenter, the *Vitias* weighed anchor on the 26th, and departed.

Dr. Maclay was soon left practically alone, and dependent entirely upon himself, for the Polynesian servant died early in December of a chronic fever which he had when he started, and the Swede soon followed suit, with the exception, that he did not die, but by constant ailing was a source of much encumbrance to his master.

As the natives were very distrustful, scarcely answering any questions, Dr. Maclay did not make much progress with the essential task of learning the language. Not only, however, were they suspicious, but determined to discourage the presence of the stranger by shooting arrows close to his head and neck, and pressing their spears so hard against his teeth, that he was constrained to open his mouth. Finding that he did not only not take the least notice of these annoyances, but that all his actions toward them were good (for, he being a doctor, his utility in the economy of the community was soon discovered), they concluded that he was no ordinary mortal, but that he was the veritable man-in-the-moon ("Kâramtâmo"), and paid him due respect accordingly.

As there were footpaths only in the neighbourhood of the villages, and as these latter were never found at a greater elevation than 1,500 feet, Dr. Maclay had some difficulty in making expeditions without guides, which at first were difficult to procure.

During his stay in New Guinea Dr. Maclay studied the inhabitants of the whole coast of Astrolabe Gulf; the people of the mountains round the gulf, and the dwellers on the islands near Cape Duperré, one of the boundaries of the gulf, who lived a life of such perfect peace that he called the islands "the Archipelago of Contentment."[‡] The inhabitants, too, of Dampier Island (Kar-kar) paid him visits. The inhabitants of "Maclay Coast," by which name Dr. Maclay proposes to call the coast skirting the edge of the Astrolabe Gulf, were of especial interest, as it seems that they have never been in intercourse with any civilised people, for not only were all their tools and weapons made out of stone, wood, or bone, but no trace of any European article could be found among them. These people treasured up, or exchanged as valuable, the smallest trifles which were given them, *e.g.* fragments of broken bottles, with which they shaved themselves, as a substitute for flint, or the sharp edges of grasses.

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[*] "Anthropologische Bemerkungen ueber die Papuas der Maclay Küste in Neu Guinea." Reprint from the *Naturkundig Tijdschrift voor Nederlandsch Indie Deel* xxxiii. *Mijn Verblijf aan de Oostkust van Nieuw Guinea. Ibid.* (Batavia, 1873).

[†] Only 7 feet broad, and 14 feet long, and divided by a screen of sailcloth into two rooms, one for his servants, the other for himself. The hut was situated on the south coast of Astrolabe Gulf, midway between the two capes, its boundaries.

[‡] "Archipel der zufriedenen Menschen."