# "...with mathematic precision" On the Historiography of the Dynamometer

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The following presentation is focused on the technology, operation and materiality of a rather specific device in a likewise specific period of time: the dynamometer as a means to measure human force in nineteenth century physiology. The corresponding scene for this instrument is the laboratory, not tied to scientific methods alone, but in its different indoor/outdoor-, institutional/individual-settings. As a typically modern space for the production of knowledge it opposes the traditional study and the forthcoming consulting room with their skeptical, even denying attitude towards equipment, machines or motors. In these various spaces of knowledge, the dynamometer contributed to establish different kinds of measuring, writing/ reading and timing procedures.

# Field Research

In October 1800, two ships, the "Géographe" and the "Naturaliste," left their home port Le Havre (France) to sail south in the direction of New Holland and Timor. This journey has gone down in history as one of the first expeditions with an explicit anthropological research mission. One of the scientists on board is the physician François Auguste Péron, a student of Lamarck and Pinel at the École de Médecine in Paris. His task: to document the health of the various island dwellers. His hypothesis: contrary to eighteenth century belief, there is no causal relation between physical degeneration and progress of a given civilization. In his published report on the "Voyage de découvertes aux terres australes," Péron claims that one must assume that the state of savageness is actually a state of feebleness (ibid., p. 470).

To confirm this hypothesis the physician included a "dynamometer" in his equipment (ibid., p. 446 f.). This instrument had been invented and made public by the French rifle maker Edmé Regnier two years earlier in 1798:

Dynamometer according to Regnier from: Regnier, Edmé. 1798. Description et usage du dynamomètre, p. 179.

Regnier's dynamometer weighed about one kilogram, consisted of an oval steel clasp, a measuring plate with a dual scale (in myriagrams and kilograms), a pointer, as well as a multi-pieced rig from which to hang the apparatus. This made it possible to measure exactly both tension and pressure, be it from humans, horses or even machines (Regnier 1798, p. 160 ff.).

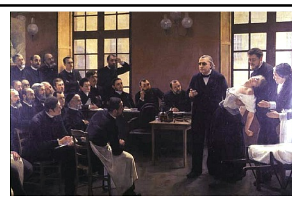
But the numbers recorded were only *comparative*, *never absolute* which is, indeed, what Péron had in mind, as he wanted to measure the muscular strength of the natives against that of the Europeans (represented by the crews aboard the two ships). As a consequence, Péron discovered a *hierarchy of physical constitution* (Péron 1807, p. 457) among the ethnic (or national) groups involved. The results delivered a statistical average value for the amount of force the subjects were capable of pushing; first using both hands, and second using their back:

from: Péron, M. F. 1807. Voyage de découvertes aux terres australes, p. 484.

This was, incidentally, a confrontation which cast its spell over much of the nineteenth century: either *via the outside* (in Péron's case), or, as we see in the example of the Turin-based scholar Cesare Lombroso, as a search for the *foreign element within one's own society*, an element which comes to be identified as "uomo delinquente" (Lombroso 1876). Lombroso also refers to muscular strength as one of the "stigmata degenerationis" (ibid, p. 229 ff.), qualities which he attempted to show objectively with the help of measurements taken with the dynamometer (ibid, p. 530). A great admirer of Franz Joseph Gall, he deemed it possible to draw conclusions on the nature of the soul via physical attributes and vice versa.

# The Clinic

The Parisian Hôpital de la Salpêtrière under the direction of famous neurologist Jean-Martin Charcot provides an excellent example. The Salpêtrière was a former gunpowder factory reconstructed as the largest female-hospice in France: More than 3,000 women – hysterics, vagabonds, prostitutes etc. – resided in a space of one quarter million square meters. It was a spectacle of madness, but also a mad spectacle. The Salpêtrière served as Charcot’s stage. There, the neurologist found everything that was needed for setting the scene: first of all, the amphitheater, where the maestro would present his Leçon du mardi, a demonstration lecture which has been passed on to us by Pierre-André Brouillet in a well-known painting.



Pierre-André Brouillet: Une leçon clinique du
Dr. Charcot. Oil painting, 1887, Musée de Nice.

We see a room, illuminated by lamps and tall windows, divided in a realm for the viewers and one for the stage. The composition includes an audience, several assistants and the director himself in the role of the instructing physician accompanied by his protagonist, a hysterical woman, nearly bare and almost unconscious. Opposite Charcot hangs a board (occasionly cut off from the figure like here): as a picture-within-a-picture it provides stage directions which demonstrate what will be diagnosed on the stage, namely phase 2, figure G from the synopsis of the hysterical breakdown (see also Richer 1881, p. 168).

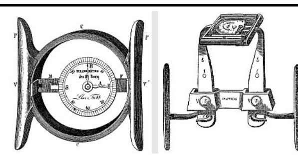
Furthermore, on the right edge of the stage painted by Brouillet on top of a table lie the instruments to be used during the diagnosis and treatment. Unfortunately, no dynamometer is to be found on this particular table. From the writings of one of Charcot's assistants, Charles Féré, however, we know that it was commonly used in the Salpêtrière: for example, (Féré 1887, p. 9 – acknowledging Péron on p. 4) a device from Duchenne de Boulogne, who not only investigated electromuscular phenomena, but also designed mechanical instruments. Duchenne de Bologne's dynamometer of 1857, built by the son of the Swiss instrument maker Joseph Frédéric-Benoit Charrière, is a result of this work:

Dynamometer according to Duchenne de Bologne made by Charrière

Féré himself (1887, p. 9) used this device in a form modified by the Parisian instrument maker Charles Verdin. His experimental subjects were hysterics from the Salpêtrière, allowing him to plausibly argue that they had replaced the Helmholtzian frogs as the martyrs of science (Féré 1887, pp. 27, 347). With his dynamometer, the difference between the hands of hysterical women and twitching frogs' legs was reduced to a minimum. In both cases physiology *fuses with mathematics and physics* as well as it presupposes a *body that merely reacts to stimuli*, where the measure of the force exerted is a question of a mechanical, organic or nervous state. From that point of view the same laws of the development of force in organic nature apply as well to inorganic nature.

# The Office

As a medical intern in 1884/85, Sigmund Freud also made use of dynamometers when he performed experiments on himself using hydrochloric cocaine. Freud not merely wanted to describe the effects of the drug (as prose of a self awareness), but also to *render them objective through measurement* (Freud 1885a, 1885b). In his accompanying studies he speaks of two dynamometers, but we only know the origin of one of them, namely that designed by the French neurologist Victor B. Burq, who even constructed two different apparatuses:



Two Dynamometers according to Burq, built by Lüer (left) and Charrière (right)

Freud's first series of experiments (taking cocaine twelve times over six weeks in amounts of 0.05–0.10 g.) already provides all the important results, most notably the "wonderfully stimulating effect of coca" (Freud 1884, p. 301 f.). Below are the experimental results from November 9th, 1884:

From: Freud, Sigmund. 1885. Beitrag zur Kenntnis der Cocawirkung, p. 131

Table showing results of Freud's dynamometer trials under the influence of cocaine. The left column gives the times the trials were made each day. The right column adds notes on the subjective state of the test subject ("tired", "euphoric", etc.). The middle columns are giving the read offs from the dynamometer, the maximum and average values.

Accordingly the future psychoanalyst not only transformed his private office into a laboratory, thus uniting the experimenter and the test subject in one person but also carried on a *knowledge of the body which is not based primarily on the written word as its constituting medium*. Before this knowledge could even appear as a manuscript, it was isolated as a data point on the scale of a dynamometer "with mathematic precision" - just as Carl Ludwig had called for in his 1852 *Textbook of Physiology* (p. 2). Scientific prose takes a back seat to methods based on measurement, which are accompanied by forms of numerical notation.

# The Text

Under French physiology's sphere of influence we also find Friedrich Nietzsche. A philologist by education, he mentioned the dynamometer several times in his texts, aphorisms and fragments. Mostly he refers to Féré's work *Dégénérescence et criminalité*, which was in his possession (see Nietzsche 1888, KSA 13, pp. 410, 499). The background leading up to Nietzsche's reading of Féré was initially his occupation with the "problem of decadence" – his criticism of Wagner is teeming with terms from the Salpêtrière school, as well as he calls Socrates a "monstrum in fronte" (Nietzsche 1889, KSA 6, p. 69, cited from Féré 1888, p. 80, who refers here to "l'œuvre de M. Lombroso") – rather the intention to ground every work of art in a physiological foundation (Nietzsche 1889, KSA 6, p. 418).

Excerpt from: Féré, Charles. 1888. Dégénérescence et criminalité, page 80. Marks by Nietzsche (Nietzsches copy, Klassik Stiftung Weimar).

Nietzsche's argued as follows. Firstly, the dynamometer can be used to measure tragic emotions. Thus, in contrast to Aristotle's teachings, it is possible to show that a tragedy functions as a "tonicum", not a "purgative agent" (Nietzsche 1888, KSA 13, p. 409 f.). Secondly, dynamometers lend objectivity to aesthetic impressions, for wherever we see strength wither, something ugly is also at play, and wherever it increases, something beautiful (ibid, p. 282 – along the lines of Féré 1888, p. 61). And thirdly, dynamometrics is capable of assigning a numerical value to erotic tension; anyhow the presence of members of the opposite sex in the audience results in increased performance of physical strength, on the part of the test subjects (according to Féré 1888, p. 3 f.) In this manner, boundaries of the clinic were lifted, allowing its knowledge to be applied to everyday interpersonal relationships.

# The Factory

Around 1900, driven by the increasing and spreading industrialization, physiology began to dedicate itself to *optimizing the worker's body*. The keyword is "fatigue" (Rabinbach 1992), understood to mean a quantitative limit of human exertion in a working world which is no longer defined by craftsmanship, but by machines, under the auspices of factories, automation and the division of labor (Münsterberg 1917, p. 3 ff.).

Dynamometers listed in the catalog of Münsterberg's
Psychological Laboratory, Harvard 1893

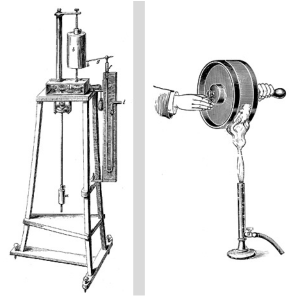
With physiology's step out of the indoor-laboratory, not only science and business merge (in order to supply the industry with criteria for selection), but also the economics of the body, the factory and the nation – as the formation of *physio-social energetics*.

With this transition to the science of fatigue, however, physiology does remain loyal to its instruments of objectivity, including the dynamometer, which at that point and after several modifications has come to be known as an ergograph. It was developed in 1884 by Angelo Mosso, a physiologist from Turin, Italy, and consists of two parts: a positioning apparatus, with a supporting plate for the arm and metal tubes which keep the index and ring finger still, as well as a recording device with a metal pin and goose quill that moves via a tension wire with leather band, weight and pulley (Mosso 1891, pp. 104, 107 ff.).

Ergograph according to Mosso (Caspari 1911)

The strength of the middle finger is measured as the subject moves his finger, either on his own at a given tempo, supplied by a metronome, or as the finger contracts in response to electric stimuli.

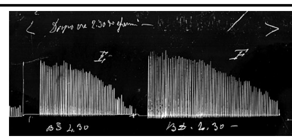
According to Mosso's experimental setting the only thing missing in his preceding figure is the flame-blackened rotating cylinder, called a "kymograph" or "wave recorder":



Kymograph for measuring blood pressure according to Ludwig, 1847 (left) and Blackening equipment including gas burner and the blackening nozzle by Jaquet (right)

Thus, an individual *fatigue curve* could be drawn on the slowly rotating cylinder. The char layer was fixed with a layer of shellac after the recording had been taken.

Of particular importance is that with the ergograph, the results of the measurement no longer need to be read off and then transcribed into tables, rather a diagram is drawn in real time. Bodily functions are transferred into unprecedented images, as they are mechanically created, not painted or drawn. *Towards the end of the nineteenth century, graphic interfaces emerge between the body and its numerical values*. The method is indebted to the "inscriptions" of Marey (1878, p. VIII, XII) and signifies a *break within the history of knowledge* in that it signaled the *transition from discrete notation to continuous registration* (Mosso 1891, p. 104), and also brought about a renewed *fusion of image, writing and numbers*.



Fatigue Curve, 1890 (detail). Bequest Angelo Mosso (Biblioteca Mosso, Torino)

The use of the ergograph shows how swiftly the interest of research shifted from minimum or maximum force values to the progression or digression of these very values. Just as Marey (1868, pp. 11 f., 93 and 1878, p. VI) used musical notation and Cartesian geometry as a model for his graphical method, Mosso worked towards the *registration of temporal phenomena*. His main focus lay in intervals of fatigue, those fleeting processes which couple human strength with time. *Every ergograph also serves as a chronograph*: its diagrams are based on a coordinate system – even when this is accompanied by the fact that time was just as *homogenized* as it was *linearized* on the recording cylinder.

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