The conservation of nervous energy: Neurophysiology and energy conservation in the work of Sigmund Exner and Josef Breuer

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Abstract

This article explores the assimilation of the law of energy conservation in the psychological sciences of the late nineteenth century by comparing two similar neurophysiological projects conceived in largely the same social milieu and at the same time – namely, Sigmund Exner's *Project for a physiological explanation of psychic phenomena* (1894) and Josef Breuer's "Theoretical" chapter for *Studies on* Hysteria (1895). As shall be demonstrated, even within the narrow context of *fin-de siècle* Viennese neurophysiology, energetic concepts were used in apparently similar models, but defending widely distinct perspectives on life and the mind. While Exner formulated his project with a view of reducing mental processes to the exchange of neuronal energy, thus eliminating remnants of vital force in psychology, and generally following the methodological precepts of organic physics and of the thermodynamic method, Breuer in turn formulated a model whereby the electricity of neuronal exchanges was considered equivalent to a modified version of vital forces. Although the difference in their approach cannot be reduced to a single factor, the article suggests that the role played by medical practice in theory-construction provides one key condition for the variation in their otherwise analogous projects. While Exner conducted his work exclusively within the physiological laboratory, and still shared the "therapeutic nihilism" characteristic of the Second Vienna Medical School, for Breuer instead theory was both intimately allied with, and secondary to, his medical practice.

Neurophysiology and energy conservation: the cases of Sigmund Exner and Josef Breuer

Introduction

Energetic models were ubiquitous in the psychological sciences of the late-nineteenth to mid-twentieth century. Scientists with projects as widely distinct as Gustav Fechner, Wilhelm Wundt, William James, Pierre Janet, Sigmund Freud, and Ivan Pavlov, amongst many others, made use of notions of force and/or energy to explain mental phenomena at some point in their work. Although their use of the concept(s) showed marked differences, they all emphasized the need for the psychological sciences (neurophysiology, psychology, psychiatry, psychoanalysis) to frame the activities of the mind and/or brain around the concept of a quantity – conceived as a force or energy – that would at least partially explain some features of our mental functioning.

Since Ernst Mach's early contribution (Mach, [1872] 2014), an extensive scholarship in the history of sciences has been devoted to analysing the history of the concept of energy (Harman, 1982; Delon, 1988; Smith, 1998), of the "discovery" of the law of conservation of energy (Kuhn, 1959; Elkana, 1974; Cohen, 1981; Caneva, 1993, 2021), as well as of exploring the intrinsic relations between energy, culture, and society (Brantlinger, 1988; Smith and Wise, 1989; Neswald, 2006; Wise, 2018). Substantial attention has also been given to the reception of concepts of force and energy in the life sciences (Lenoir, 1982; Haigh, 1984a; Kremer, 1984; Rey, 2000; Stollberg, 2000; Williams, 2003; Reill, 2005; Zammito, 2017; Gambarotto, 2018). A more recent and quickly growing body of scholarship has explored the impact of energy in the arts and literature (Clarke and Henderson, 2002; Gold, 2010; Kahn, 2019), while the new field of energy humanities, which explores the ways in which energy shapes society, has started to take form in the last few years (Szeman and Boyer, 2017; Turnbull, 2021).

Assessments of the assimilation of energetic principles in the human sciences, however, are still surprisingly sparse given its widespread impact – which ranged from psychology to sociology, political economy, the sciences of work, the educational sciences, and further. Over thirty years after its publication, Anson Rabinbach's now classic *The Human Motor* (1992), which argued that thermodynamics provided a single conceptual chain linking nature, machines, and humans that underlined the modern emphasis on productivity, remains the guiding analysis of the matter in the field.

When it comes to specific evaluations of the reception of energetic principles in psychology, little work has been exclusively dedicated to the topic. Although historians of psychology and philosophy dealing with turn-of-the-twentieth-century authors will sometimes reference the debate, particularly when discussing the impact of materialism in the physiological psychology of the time (Ash, 1995, pp. 61–67; cf. Danziger, 1997, pp. 62–65), the theme is seldom the exclusive focus of the attention of scholars.

A notable exception is Sergio Franzese's *The Ethics of Energy* (2008), dedicated to exploring the topic in the work of William James, and to my knowledge the only (albeit short) monograph devoted to the theme. Laurent Fedi explored Bergson's critique of the application of conservation of energy in psychology (2001). More attention has been given to psychodynamic authors: Robert Holt explored the concept of psychic energy in Freud (1989), Sonu Shamdasani analysed in greater length the background and uses of energy by Jung (Shamdasani, 2003, pp. 202–270), while Sebastian Normandin explored the theme in the work of Reich (2013). All of these analyses, however, are circumscribed to understanding the function of these concepts in the authors explored, not usually taking into consideration that this was a pervasive thematic in the psychologies of the period. Virtually every author in psychology had to contend with the question of the consequences of energy conservation for their science – either to accept or reject it.[1]

Even though the concepts of force and energy had featured in the psychological sciences long before the turn of the century,[2] the discovery of the law of conservation of energy in the 1840s and the subsequent development of thermodynamics in the late-nineteenth to early-twentieth century transformed these terms and, therefore, how other scientific disciplines would come to receive them. In 1847, Hermann von Helmholtz published the seminal essay *Über die Erhaltung der Kraft* [On the Conservation of Force] (1847). Helmholtz and his colleagues, Emil du Bois Reymond, Ernst Brücke, and Carl Ludwig, turned the law into the foundation for their approach to physiology – described by du Bois Reymond as an 'organic physics' (1918, p. 122), and later titled as such by scholars (Lenoir, 1982; Finkelstein, 2013; Cahan, 2018; Wise, 2018; Caneva, 2021).

Although there is no single definition of organic physics, the approach was primarily defined by its emphasis on experimentation, by the attempt to reduce any natural phenomena – and particularly organic phenomena – to the mechanics of attraction and repulsion, and by the use of the "thermodynamics of life" method. According to this, an organism or organ is considered a closed system or "black box," so that intermediate phenomena inside the organism are ignored, and only exchanges between the system and the environment were taken into consideration. Therefore, in this methodology

[1] Wilhelm Dilthey, for instance, proposed this as the distinguishing marking criteria between the "descriptive psychology", concerned with the lived experience (*Erlebnis*) and reflexive awareness (*Innewerden*), and the "explanatory psychology", which 'seeks to explain the constitution of the psychic life with the help of its components, energies and law' – a distinction that he would later re-elaborate as the dividing line between the natural and the human sciences (Dilthey, [1894] 1977, p. 23)

[2] To remain within the German context, the psychology of Herbart (1824) and, yet earlier, that of Christian Wolff (cf. Mei, 2021), represent prominent examples of dynamic psychologies conceived as systems of forces analogous to Newtonian forces. The same is true of energy. In 1835, the physiologist Johannes Müller formulated his *Law of Specific Nerve Energy*, the doctrine that the different sensory organs are connected to the external world via five different types (or "energies") of sensory nerves (Müller, 1838). Stanley Jackson traced the origins of the use of "nervous force" back to the seventeenth century in the works of physiologists William Croone, Thomas Willis, Giovanni Borelli, and in Isaac Newton's theory of propagation of the spirit by forces of vibration of the nerves. Jackson further noted that in the eighteenth century, the "kindred notions" of force, energy and power, as applied to the nerves, were generally used as synonyms without a consistent convention (Jackson, 1970b, 1970a).

'direct knowledge is limited to what passes in and out of the system' (Kremer, 1984, pp. 13–14). Further, the method assumes that the conservation principle can be applied to closed systems, where over time the system as a whole remains in equilibrium. This entails that for the condition of equilibrium to be maintained, whatever enters the system must somehow be balanced by something leaving; following this, nothing can leave the system that is not contained in the materials entering it. When applied to an organism, this entails that any work produced must have an equivalent consumption of food and oxygen, leaving, therefore, no room for explanations based on the concept of vital forces (*Lebenskräften*).

By the 1870s, their scientific and institutional success had turned organic physics into the predominant approach to physiology in Germany – and, thanks to their efforts in promoting their work internationally, becoming also popular in France, England, Russia, Italy, and the USA. Taking into account Edwin Boring's still apt observation that the new psychology of the nineteenth century 'was really physiological psychology' (1950, p. 425), the energetic accounts assimilated by turn-of-the-century psychologists most often referenced Helmholtz's physiological formulation of the law of energy conservation – as opposed to the physical or chemical formulations by the likes of J. Mayer, J. Joule, L. Colding, W. Grove, B. Clapeyron, amongst others.[3]

As Flavio Bevilaqua explained in his detailed analysis of Helmholtz's essay, the original concept there had been that of *Spannkraft* or tension force, which Helmholtz contrasted with living force (*lebendige Kraft*) as work: 'with tension forces we are very far from the concept of work and very close to that of potential energy' (1993, p. 316). *Spannkraft* or potential energy made it possible to conceptualise labour power (*Arbeitskraft*) as a mechanical quantity that could be stored and converted but never added to or destroyed.[4] The principle of energy conservation allowed the cosmos to be apprehended as a vast reservoir of labour power awaiting its conversion to work, as a system of production whose product was a universal energy necessary to power the engines of nature and society and, as Rabinbach observed, for authors in the period the human body came to be conceived as 'the site of conversion, or exchange, between nature and society', which allowed its application to the emergent human sciences (1992, p. 3).

In his in-depth analysis of the impact of thermodynamics in nineteenth-century physiology, Richard Kremer contended that energy conservation at the time took on the status of 'an all-encompassing natural law, unifying all sciences just at a time when disciplinary and institutional specialization seemed to be permanently fragmenting the scientific enterprise' (1984, p. 452) – by which he particularly meant

[3] Helmholtz' formulation of the law of energy conservation was in fact conceived alongside and largely derived from his physiological work on the origin of animal heat via consumption of foodstuffs and respiration (Lenoir, 1982; Kremer, 1984; Bevilacqua, 1993; Jurkowitz, 2010; Caneva, 2021).

[4] Helmholtz would only start using the term energy in the 1880's, when he returned to work on the topic of heat. This is also when he formulated the concept of free-energy, by distinguishing between a part of energy that appeared as heat from a part that remained "free" to be converted into other kinds of work (cf. Kragh, 1993).

the natural sciences. His thesis can also be extended to the emergent human sciences, in disciplines such as psychology, sociology, and political economy. Within the context of "crisis" and fragmentation of science in the late-nineteenth century,[5] the concept of energy allowed for the unification of matter, life, the mind, and society by providing a single common currency capable of being circulated within widely different domains, as well as being further assimilated with various local traditions and epistemic practices by formulating energetic concepts specifically adapted to each field.

Psychologists were therefore compelled to consider the impact of energy conservation – and later, also entropy – in their emergent science. In either trying to make use of the theoretical framework of the organic physics group, or rejecting their mechanistic view of life, the "new" psychologists engaged in broader debates on physiology – and, in particular, on teleology and vital forces. In assimilating conceptual frameworks from physiology to psychology, these psychologists re-enacted models, problems, answers, and disputes analogous to the debate classically described as mechanism vs. vitalism that were at the centre of the life sciences from the eighteenth to the mid-nineteenth century (Lenoir, 1982; Rey, 2000; Williams, 2003; Reill, 2005; Duchesneau, 2012; Normandin and Wolfe, 2013; Zammito, 2017; Gambarotto, 2018; Wolfe, 2019).

The assimilation of the "global" principles of energy conservation was, however, intrinsically local, and the specific forms energetic concepts took in the psychological sciences reflected the problems and practices for which they were formulated. In the life sciences, the reception of energetic concepts from physics was informed by the specific problems of the field, such as purposiveness, organisation, generation, evolution, and growth. In psychology, instead, the mind-body problem, as well as the problem of the origins of qualities of consciousness, morality, free will, education, and psychopathology received particular consideration from authors at the time, and have shaped the reception of these dynamic and energetic concepts in the science.

This paper aims to provide one poignant illustration of this process, by comparing two similar neurophysiological projects conceived in largely the same milieu and at the same time – namely, Sigmund Exner's *Project for a Physiological Explanation of Psychic Phenomena* (1894) and Josef Breuer's "Theoretical" chapter for *Studies on Hysteria* (1895). As shall be demonstrated, even within the narrow context of *fin-de siècle* Viennese neurophysiology, energetic concepts were used in apparently similar models, but defending widely distinct perspectives on life and the mind that were intrinsically informed by their purposes. While Exner formulated his project with a view of reducing mental processes to the exchange of neuronal energy, thus eliminating remnants of vital force in

[5] The first announcement of a "crisis" in psychology was made by the Swiss philosopher-psychologist Rudolph Willy, who in 1896 already diagnosed a growing fragmentation within psychological research. As Annette Mülberger showed, his assessment emerged at a time when a debate on the fundamental problems of psychology was undergoing between Wundt and Avenarius (Mülberger, 2012; Sturm and Mülberger, 2012). See also Russo Krauss (2019) for a more detailed analysis of the debate Wundt-Avenarius.

psychology, and generally following the methodological precepts of organic physics and the thermodynamic method, Breuer, in turn, formulated a model whereby the electricity of neuronal exchanges was considered equivalent to a modified version of vital forces. Although the difference in their approach cannot be reduced to a single factor, I suggest that the role played by medical practice in theory-construction provides one key condition for the variation in their otherwise analogous projects. While Exner conducted his work exclusively within the physiological laboratory, and still shared the "therapeutic nihilism" characteristic of the Second Vienna Medical School (Johnston, 1972; Luprecht, 1991), for Breuer instead theory was both intimately allied with, and secondary to, his medical practice.

'The riddle of consciousness is solved'

Born into 'Vienna's foremost scientific dynasty' (Coen, 2007, p. 3), Sigmund Exner von Ewarten (1846-1926) already from the beginning of his medical studies, in 1865, came under the tutelage of Ernst Brücke. After moving to Vienna in 1848, Brücke brought along to the city the organic physics approach to physiology that he had developed together with the friend and colleagues du Bois Reymond, Helmholtz, and Carl Ludwig in Berlin.[6] Brücke guided his pupil onto the highest Viennese academic rankings: in 1867-68, he sent Exner to Heidelberg to study with Helmholtz; in 1871, only one year after graduating, Exner was appointed lecturer (*Privatdozent*) under his recommendation. Exner became extraordinary professor (*ausserordentlicher Professor*) in 1875, and in 1891 inherited Brücke's chair at the institute. As a disciple of Brücke and Helmholtz, Exner's initial field of work had been sensory physiology, where he produced important work on colour perception and visual memory, being also – amongst many achievements – the first to note that the periphery of the retina had the function of perceiving movement (Exner, 1886a, 1886b). He also conducted important work in the field of brain localisation (Exner, 1879, 1881), being the first to conceive of the notion of neural networks (Breidbach, 1999, 2016).[7]

In *Entwurf zu einer physiologischen Erklärung der psychischen Erscheinungen* [Project for a physiological explanation of psychic phenomena],[8] Exner synthesized more than twenty years of research into a highly speculative book, to formulate a treatment of psychological activity as a balance of the physiological states of excitation, be reducible to the organisation of neural connections, and to

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[6] Ludwig also lived in Vienna between 1855-1865 as professor of physiology and physics at the Joseph's Military-Medico Academy. As expressed in the vivid letter written by the visiting student Ernst Haeckel to his parents, together they turned physiology in Vienna synonymous with the organic physics approach (Haeckel, [1857] 1978).

[7] For an in-depth treatment of Sigmund Exner's biography and of his family, see Coen (2007).

[8] For a more detailed analysis of *Entwurf*, see Breidbach (1999).

the facilitations[9] and inhibitions amongst nerve cells. In his words, the purpose of the monograph was to:

> ...trace the most important psychic phenomena back to the gradations of states of excitability (*Erregbarkeit*) of the nerves and nervous centres, tracing in this way everything that appears to us in consciousness as a manifold to quantitative relations, and to the difference in the central connections of otherwise essentially similar nerves and nerve centres (Exner, 1894, p. 3).

Physiology, Exner argued in the introduction, in reference to the work of the organic physics group, had over the last fifty years progressively replaced explanations of organic phenomena that relied on notions of vital forces with explanations based purely on descriptions of 'chemical and physical processes.' Although this knowledge was not yet sufficient to fully account for all vital phenomena, the evidence accumulated so far seemed to indicate that the hypothesis of vital forces was superfluous. 'Only a group of these proved to be an exception,' however, 'the so-called mental (*seelischen*) phenomena; a type of vital force remains a hypothesis for most natural scientists under the name of mind/soul (*Seele*)' (ibid., p. 1). The underlying motivation of the monograph was therefore that of providing a quantitative explanation of psychic phenomena that would eliminate both the concepts of vital force as well as of mind/soul, thus extending the organic physics approach into the realm of psychology.

In the monograph, Exner built his model starting from the most basic phenomena, moving progressively towards complex mental processes. The simplest form of reflex, he said, is found in the legs of frogs, which move after a simple touch. A central concept introduced there is that of release (*Auslösung*). Stimuli, argued Exner, have the effect of releasing reflexes (ibid., p. 51ff.). He introduced a mechanical metaphor to illustrate his point: when I pull on a rope attached to a bell clapper, I transfer energy from my muscles to the mass of the rope and clapper, thereby generating movement and sound. If, however, the rope is elastic, the energy spent in stretching the rope will remain free (*freie*, in the sense of latent). Any subsequent work done through the clapper by releasing the rope, whether in the vibrations of the bell or by sound waves, originates from the transformation of this free or potential energy (*potentielle Energie*) into kinetic energy (*lebendige Energie*). If, however – the analogy continues – at the end of the rope we find a detonator instead of a bell, the pulling of the rope leads to forces no longer correlated

[9] Exner first formulated the concept of facilitation (*Bahnung)* as the counterpart of inhibition (*Hemmung*) in an essay where he treated the interactions (*Wechselwirkungen*) between the excitations in the nervous system. Exner opened this work by saying: 'It is well known that an excitation taking place in the central nervous system can be inhibited by another excitation. I remind you of the reflex inhibitions caused by stimulation of sensory nerves or by the will. There are also a number of statements in the literature (to which I shall return shortly) which show that the reverse case also occurs, i.e. the course of excitations in the interior of the central nervous system can be favoured by the fact that other excitations are entering or have entered it. In contrast to inhibition, I will call this phenomenon, which the present paper is concerned with examining in detail, "facilitation"' (Exner, 1882, p.487). I thank Prof. Richard Simanke for bringing this essay to my attention.

with the transference of energy expended by the muscles. In this case, we have a process of release (*Auslösungsvorgang*). The explosive device already contains within itself most of the potential energy generated during the explosion, and the pulling of the rope simply activates that potential. The activation of a nervous cell in reflex behaviour works, Exner proposed, in an analogous manner.

Exner's observation is simple: if the simple stimulation of a nerve cell by touch were enough to generate movement in a frog's leg, the energy expended in the movement would be much greater than the energy supposedly causing it. If this were merely the function of an energy transfer, as in the first example, it would contradict Helmholtz's law of energy conservation. Exner, therefore, inferred that reflexes are a function of potential excitation accumulated in nerve cells through successive stimuli. The stimuli are not triggered until a certain threshold is reached, at which point excitation is transferred to the adjacent nervous cell. Exner pointed out that this accumulation process is likely chemical (ibid., p.53) and, more importantly, that it is responsible not only for the transfer of excitation in motor nerves, but also in sensory ones – which allows this model to be employed in his explanation of higher mental phenomena, such as voluntary behaviour (by which the agent learns to control the path of arousal), perception, attention, representation, intelligence, and morality, themes he dealt with in the following chapters.

The transition from simple reflex to complex behaviour is made possible by the notion of 'complex of excitation' (*Erregungscomplex*), which in turn is regulated not only by the facilitations but also by the opposite process of inhibition (*Hemmung*) – that is, the aroused nerves assemble in dynamic groups (complexes) that are regulated by inhibitory processes. Exner was familiar with the work of Russian physiologist Ivan Setchenov, who was also Helmholtz's assistant in Heidelberg during his visit, on the inhibitory motor nerves in the legs of frogs (cf. Smith, 1992). Exner extended this motor model to also encompass sensory perception. He explained, for example, the phenomenon of binocular rivalry, previously studied by Helmholtz (Helmholtz, 1867, p. 493ff.), as generated by the sensory inhibition of part of the visual field (Exner, 1894, p. 74).

In *Entwurf*, Exner for the first time applied some of the principles developed by the organic physicists to the study of mental phenomena. Helmholtz co-discovered the law of energy conservation. Du Bois Reymond, Brücke, as well as Helmholtz, were pioneers in the study of electrophysiology. None of them, however, had attempted to formulate a thermodynamic model of mental processes, whereby neuronal excitation was understood to be a function of energy consumption and its distribution. Given the impact of the law of energy conservation at the time, Exner's approach could be seen as a direct application of the law to phenomena that were already central to the work of the organic physicists, such as nerve-conduction and sensory physiology. This, however, was not the case. Both Helmholtz and du Bois had vehemently ruled out the possibility that the qualitative aspect of consciousness could be explained through its underlying physiology and material exchange. In his famous lecture, *Über die Grenzen der Naturerkennens* [On the limits of science], du Bois argued not only that consciousness was presently unexplained by its material conditions (*ignoramus*), but that it could never be explained by them (*ignorabimus*) (du Bois-Reymond, 1872). Similarly, Wilhelm Wundt, who had been a student of du Bois-Reymond in Berlin, as well as an assistant to Helmholtz in Heidelberg from 1858 to 1865 (Araujo, 2014), maintained that:

> It is never possible to arrive, by way of a molecular mechanics, at any sort of psychical quality or process. […] Psychical processes refuse to submit to any one of our physical measures of energy; and the physical molecular processes, so far as we are able to follow them, are seen to be transformed, variously enough, into one another, but never directly into psychical qualities (Wundt, [1880] 1904, p. 102).

Wundt did not deny that energy conservation played an important role in regulating the physiology underlying mental phenomena. He saw the nervous system as the 'central station from which all the processes of the animal body are directed' (ibid., p.65). The nervous system, like any other form of organic matter, is made up of 'chemical compounds' that 'contain the stock of potential work, which under the influence of external stimulation is transformed into real work' (ibid., p.66). Wundt, however, excluded the possibility of deriving psychological qualities from this material exchange. Exner, who was familiar with Wundt's work and must have also met him in Heidelberg as Helmholtz's assistant, argued precisely that. The epistemological leap he took, and which Wundt and the organic physicists denied,[10] lied with the addition of his proto-connectionist framework (cf. Breidbach, 1999), whereby psychical events (and mental qualities) were seen as identical to patterns of neuronal arousal and – especially – to the organization of its facilitations (i.e., to neural networks), rather than to any specific quality of nerve cells. In *Entwurf*, Exner made this argument explicit in chapter VI (*Perceptions*), section 1 (*Excitations in the organ of consciousness*):

> The organ of consciousness consists of nervous facilitations in the broadest sense of the word and:
>
> α) All phenomena of qualities and quantities of sensations, perceptions and conscious representations can be traced to quantitatively variable excitations of different parts of these sums of facilitations.
>
> β) Two sensations are identical for consciousness when the same cortical facilitations are excited to the same extent by the sensory stimulus.

[10] Although Wundt in his earlier works denied that energetic principles were applicable in the explanation of psychological phenomena, in his later works, starting with *Logik* (1880–1883), he would coin the term *geistige Energie* (mental energy) to designate the magnitude of any mental value in relation to its proper capacity for mental action (Araujo, 2015). The term stood however in contrast with the constancy of physical energy, since it implied that the energy in question was unlimited – as stated by his "principle of growing mental energy" (*Prinzip wachsender geistigen Energie*), developed in his *Ethik* (1886).

> γ) Two sensations are similar if at least a part of the cortical facilitations excited in both cases is identical.
>
> δ) The quality of sensation and its local signals (*localzeichen*) are therefore the result of the excitation of different facilitations in the cerebral cortex (Exner, 1894, p.225)

'In this way', he completed, 'the riddle of consciousness is solved' (ibid., p.278) – a statement in a clear allusion to du Bois Reymond's lecture *Die Sieben Welträthsel* [The Seven World-Riddles], where he repeated his view that the problem of the 'emergence of consciousness' represented a hard limit to our knowledge of nature (du Bois-Reymond, [1880] 1912).

Gustav Fechner, a recurrent source of Exner's, had already at least since 1851 proposed a theory of the mind-body relation founded on their identity – what he called the 'identity view'. Fechner proposed a type of "dual-aspect monism" whereby reality is composed of only one type of substance that can be perceived from two distinct perspectives (internally or externally), like the two sides of a coin (Heidelberger, 2004, pp. 73-116;165-190). Unlike the non-reductive monism of Fechner, however, the identity theory proposed by Exner monism that sought to eliminate or to reduce the psychical to the physical – an analogous distinction to the type vs. token identity theory in contemporary philosophy of mind (Davidson, 1980).

A question therefore arises as to why this type of project was first carried out by Brücke's Viennese students, and not by those of his colleagues Helmholtz and du Bois Reymond in Heidelberg and Berlin (such as Wilhelm Wundt and Julius Bernstein), or yet by those from Carl Ludwig in Leipzig (as Adolf Fick). In my view, the answer goes through a union of conditions uniquely found in Vienna. On the one hand, the thermodynamic method and the model of physiology as applied analytical mechanics, as formulated by the organic physicists and taught in Vienna by Brücke. On the other, the neuroanatomical project of psychiatrist Theodor Meynert, a recurring reference in Exner's work. Meynert had been responsible for bringing the new somatic psychiatry form Berlin to Vienna, by formulating a model of brain functioning that almost directly translated the principles of association psychology into physiology. For Meynert, an association of ideas or sensations was identical to an association of cortical cells through projective fibres (Meynert, 1884; Guenther, 2015, p. 13ff.). It is the union of this doctrine with the thermodynamic method that enabled Exner to formulate a model of the nervous system that identified the connections between nerve cells and their energetic (i.e., electrical and chemical) exchanges with the qualities of consciousness.

We can attribute to Exner the precedence in establishing this alliance, which in turn set the framework for succeeding authors to either follow or reject it. As noted previously in the case of Wundt, it is not that the consequences of the law of energy conservation for mental life had not occurred to previous researchers; they simply could not see how to bridge the gap between the quantities of neuronal excitation and the qualities of consciousness. Another example can be found in Josef Paneth,[11] who in 1885, nearly nine years prior to Exner's *Entwurf*, wrote an unpublished short essay titled *Die Erhaltung der Energie auf Psychischen Gebiete* [Conservation of Energy on Psychic Realms]. In the essay, Paneth examined the question and concluded that '[t]he law of conservation of energy has no application to psychological processes because in the latter there is no work in the mechanical sense' (Paneth, [1885] 2007, p. 103). Unlike other vital processes, which are quantitatively determined, mental processes, he contended, produce no work in the mechanical sense because the qualities of consciousness are exclusively form-determining (*formbestimmend*). The doctrine Exner inherited from Meynert allowed him to erase the gap between quantity and quality by postulating their identity.

As Paneth died in 1891, we are left to speculate on whether Exner's *Entwurf* might have changed his views.[12] The year following the publication of *Entwurf*, however, Josef Breuer and Sigmund Freud wrote two remarkably similar works – namely, Breuer's "Theoretical" chapter for *Studies on Hysteria* (1895) and Freud's *Project for a Scientific Psychology* (1895). Despite some significant differences, both texts are based on a similar structure and largely inspired by Exner's, where the notions of facilitation, sum of excitation (conceived as a form of potential "free" energy) and inhibition played central roles. Differently from Exner, however, Breuer and Freud aimed not only at describing a neurophysiological mechanism but also at explaining how such mechanisms could lead to psychopathological phenomena. This inexorably led them to deal with problems of adaptation and regulation, which were mostly absent in Exner's account. In order to address issues in the (mis-)adaptation between a brain and its environment, they embedded these mechanisms into a wider framework, understanding them as functioning according to a 'principle of constancy of excitation,' a concept adapted from Fechner (1873). As well shall see in what follows in the case of Breuer, the notion of "sum of excitation" (*Erregungssumme*) takes on a more teleological connotation which brought back eighteenth-century vitalist notions of *Œconomia Animale*.

'That is why we are vitalists'

[11] Josef Paneth (1856-1891) served as an assistant at the Institute of Physiology under Brücke and Exner, with whom he also published a couple of studies on the cortex (Exner and Paneth, 1887a, 1887b). Paneth was a close friend of Breuer – who was also his family doctor – as well as Freud's, whom he described as the 'most lasting' of his university friendships (Paneth, 1883/2007b, pp. 44–5).

[12] Many, such as Ernst Mach, remained unconvinced. In a supplement to the fifth edition of *Analysis of Sensation*, he said of Exner's *Entwurf*: 'I have a great value for researches such as those of S. Exner, and I believe that many important problems as to physical phenomena can be solved merely by the investigation of the nervous connexions of the central organs, and by observation of the way in which stimuli are arranged in a quantitative scale. Indeed Exner's book itself is evidence of this. But I feel that the main problems still remain unsolved. For, from my point of view, I cannot conceive, any more than I could nearly forty years ago, how the qualitative variety of sensations can arise from the variation of the connexions and from mere quantitative differences' (Mach, [1914] 1959, pp. 369–370).

As a medical student,[13] Breuer had been a student of Brücke – whom he considered his most influential teacher in the medical school – and was later an assistant to Johann von Oppolzer and Ewald Hering, during which time he published important research on the topics of thermoregulation (Breuer and Chrobak, 1867; Breuer, 1868, 1869) and regulation of breathing by the vagus nerve (Hering and Breuer, 1970; Ullmann, 1971). Oppolzer's death in 1871, together with Hering's move to Leipzig the previous year, was probably the main cause of the abandonment of his academic aspirations due to the lack of institutional support. Breuer subsequently founded a successful medical practice, becoming a private physician to members of the Viennese elite. He was the family doctor to many professors at the medical school, including the Brücke and Exner families – with whom he also held close friendships.

Notwithstanding the abandonment of his academic ambitions, Breuer continued to privately carry out research in his home. His studies of the vestibular apparatus (Breuer, 1873a, 1873b, 1874, 1903; Thiele, 1975; Wiest and Baloh, 2002), jointly with Ernst Mach, were responsible for establishing that the structure is responsible for the function of the regulation of bodily balance. The "Mach-Breuer theory" of the functioning of this structure still bears their names today. Along with the friends and colleagues Sigmund Exner and Ernst Fleischl von Ewarten,[14] he was an active member of the Vienna Physiology Club, an important institution in the history of medicine and biology in the city. If Breuer ended up taking an important role in the history of psychiatry and psychoanalysis, this role, therefore, was to a large extent accidental and unplanned. And as would be expected from someone who had all his intellectual formation amid physiology, the concepts and models that Breuer employed to think about the aetiology and therapy of hysteria would inevitably go through what he learned in his training – and in particular, that of regulation. Whether discussing the topics of respiration, bodily temperature, bodily balance, or hysteria, his explanation for these would consistently use the argumentative strategy of a certain biological apparatus responsible for the regulation of a dynamic equilibrium which, when unbalanced, would lead to pathological cases.

In the *Preliminary Communication* ("On the Psychical Mechanisms of Hysterical Phenomena") from 1893, Breuer and Freud outlined a psychical mechanism that explained the aetiology of hysterical symptoms, while also presenting their newly discovered treatment – the cathartic method. In this work, they mentioned a 'state of equilibrium' found in normal mental life which, when disturbed, would lead to psychopathologies. According to the theory presented there, each pathological idea is generated because a 'painful emotion' would have been 'suppressed' (Breuer & Freud, 1893, p. 4), thus forming 'psychical traumas' (ibid., p.6). If no appropriate reaction to a salient affective event can be externalised

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[13] Unless otherwise stated, all biographical information on Josef Breuer is derived from Hirschmüller (1989).
[14] For more on the life and work of Ernst Fleischl and his relation to Brücke, Breuer, Exner, Freud and Paneth, see Medwed (1997), and Exner's eulogy of the friend (Exner, 1893).

due to ‘social circumstances or because it is something the patient wished to forget,’ thus being inhibited, they argued that the content would dissociate from the rest of the patient's mind.

They hypothesized that groups of ideas formed during these states (the so-called "hypnoid" states) could associate together, thus forming a second consciousness – a state of mental dissociation. As the grouping of ideas followed the general rules of association (similarity, contiguity), the hysterical mind can also have an idiosyncratic and apparently irrational symbolic nature – ‘a relation such as healthy people find in dreams’ (ibid., p. 5). The aim of treatment in this setting would be to bring back the synthesis between the normal mind and the hysterical mind, thus restoring equilibrium. The equilibrium in turn is achieved through the mechanism of abreaction, the cornerstone of the cathartic method presented there.[15]

Breuer's *Theoretiches* [Theoretical] chapter for *Studies on Hysteria*, published two years after the *Preliminary Communication*, aimed to provide ‘a more detailed examination’ of the notions of excitability (*Erregbarkeit*) and abreaction (*Abreaktion*) that had appeared in the earlier publication (Breuer, 1895, p. 267). The examination was based on an investigation of ‘two extreme conditions of the nervous system: a waking state and dreamless sleep.’ In this work, Breuer described a regulatory system engaged in achieving an optimal level for ‘intracerebral tonic arousal,’ which he equated to Exner's notion of ‘intercellular tetanus’ (Exner, 1894, p. 94). In *Entwurf*, as we have seen, Exner had proposed that successive stimuli caused excitation to accumulate in nerve cells until they reached a threshold at which point it was transferred to the adjacent neuron. Exner surmised that if two neurons were charged simultaneously, an "intercellular tetanus" would form between them and excitation would move between the cells. Breuer stated that excitability is what determines the conductive capacity between neurons in waking states and that its decrease or disappearance qualified states of greater relaxation of the nervous system in dreamless sleep. Throughout the text, Breuer resorted to electrical metaphors, comparing the excitatory condition of the brain, for example, to ‘a telephone line through which there is a constant flow of galvanic current’:

> …[o]r better, let us imagine a widely-ramified electrical system for lighting and the transmission of motor power; what is expected of this system is that simple establishment of a contact shall be able to set any lamp or machine in operation. To make tills possible, so that everything shall be ready to work, *there must be a certain tension present throughout the entire network of lines of conduction*, and the dynamo

[15] The idea was inspired by the work of philologist Jacob Bernays (1824-1881), who, in his 1857 essay *Grundzüge der verlorenen Abhandlung des Aristoteles über Wirkung der Tragödie* [Outlines of Aristotle's lost treatise on the effects of tragedy] (Bernays, 2004), had advocated an interpretation of catharsis as a physiological discharge of affect – a release process similar to an orgasmic reaction, vomiting or evacuation. Catharsis was understood as a way of releasing internal states that remain latent, with the aim of curing disturbing affects, and it was accompanied by a theory of emotional responses (Porter, 2015). Curiously, Jacob was also the uncle of Freud's wife, Martha Bernays, but the inspiration likely derived from other sources, since they never discussed it in their letters. His essay was profoundly influential at the time, with Nietzsche (of *The Birth of Tragedy*) being one of its most famous readers.

> engine must expend a given quantity of energy for this purpose. In just the same way *there is a certain amount of excitation present in the conductive paths of the brain* when it is at rest but awake and prepared to work' (Breuer, 1895, p. 193, my italics).

He further clarified this point in an important footnote, which, as the editor of Sigmund Freud's *Standard Edition*, James Strachey, informed us, is likely the reason Freud attributed to Breuer the distinction between "free" and "bound" energies and their relation to primary and secondary processes – a distinction that Breuer himself never made. Breuer stated that although we tend to think of sensory nerve cells as passive, this is not the case. If excitation moves from one neuron to another, 'a state of tension must exist in it.' In this sense, all nerve cells are in a constant state of mean arousal, so that the entire architectural network of the brain forms a 'reservoir of nervous tension.' This reservoir is composed of a 'potential energy' (that he also calls 'free energy') which 'lies quiescent in the chemical substance of the cell,' generating a form of kinetic energy (what Freud would later call "bound energy") 'which is discharged when the fibres are in a state of excitation' (ibid., p. 194 n.1).

Thus far, this corresponds closely to what Exner had proposed in his monograph. Exner described a model of brain function whereby excitation was accumulated "freely" or "latently" in chemical form, thus providing the neurons with the ability to trigger adjacent cells, by transforming potential excitation into kinetic excitation. Breuer further assumed that the waking brain has only a limited amount of arousal to perform its tasks. Continuing his electrical analogy, he maintained that the brain:

> …behaves like one of those electrical systems of restricted capability which are unable to produce both a large amount of light and of mechanical work at the same time. If it is transmitting power, only a little energy is available for lighting, and vice versa. Thus we find that if we are making great muscular efforts we are unable to engage in continuous thought, or that if we concentrate our attention in one sensory field the efficiency of the other cerebral organs is reduced—that is to say, we find that *the brain works with a varying but limited amount of energy* (ibid., p. 194, my italics).

Breuer attributed the notion of a limited amount of excitation (or energy) to an eighteenth-century exponent of the Montpellier school of medicine, Pierre Jean Georges Cabanis (1757-1808), who argued that 'sensibility seems to behave like a fluid whose total quantity is fixed and which, whenever it pours into one of its channels in greater abundance, becomes proportionally less in the others' (Cabanis *cit.* Breuer, 1895, p.194 n.1). In the book from which Breuer borrows the quote, the *Rapports du Physique et du Moral de l'Homme* (1796), Cabanis advocated a form of monism whereby all active forces, from Newtonian gravitation, chemical affinity, the formation of the living embryo, the instinctive animal sensitivity, to the physical substrate of moral sympathy, are all fundamentally the same force, varying merely in degree and complexity. Profoundly influenced by Theophile Bordeu, the prominent theorist of *Montpellierain* vitalism who had treated sensibility and irritability as intrinsically connected vital forces, assumed to organise all vital functions (Haigh, 1976, 1984b), Cabanis treated sensitivity as an emergent property, irreducible to physicochemical uniformities, and which irrevocably distinguished life from death. Manifested 'obscurely' in the lower centres of the body and more 'distinctly' in the brain, sensitivity, when properly studied, would reveal the secret of organic equilibrium. Cabanis envisioned a 'well-tempered' individual, in whom the sensitive and motivating forces would be perfectly balanced and in whom the stable balance of the centres of sensitivity and all bodily functions would ensure physical and mental well-being. But even this psychic and physical balance would be transitory since new needs would arise with new faculties and with the fresh exigencies of the impinging environment (Staum, 1974).

In what follows in his chapter, Breuer proposed a similar model. He described a dynamic equilibrium found in healthy people which, when disturbed, led to disproportionate affects such as those found in hysterical phenomena. Following this perspective, he argued that the organism 'tends to maintain the optimum of excitation and to return to that optimum after it has been exceeded' (Breuer, 1895, p. 274), similar to how bodily temperature is maintained at optimal levels in warm-blooded animals for the functioning of their organs:

> I think that we may also assume that there is an optimum for the height of intracerebral tonic excitation. At that level of tonic excitation the brain is accessible to all external stimuli, the reflexes are facilitated, though only to the extent of normal reflex activity, and the store of ideas is capable of being aroused and open to association in the mutual relation between individual ideas which corresponds to a clear and reasonable state of mind. It is in this state that the organism is best prepared for work (ibid., p. 273).

Although Breuer described the functioning of the nervous system with a terminology aligned with the organic physics of Brücke and Exner – using concepts such as free energy, reflex, conversion, facilitation, excitations, etc. – the underlying structure is not far removed from that proposed by the vitalist authors of Montpellier. The economic model Breuer formulated in his chapter arguably bears a greater resemblance to a model of *Œconomia Animale* as described by Bordeu in the eighteenth century (Wolfe and Terada, 2008) than to the physiological mechanism proposed by Exner. In the *Encyclopédie*, *Œconomia Animale* had been defined by Ménuret de Chamband, another disciple of Bordeu, as:

> …the order, the mechanism, the whole of the functions and motions which sustain the life of animals, the perfect and universal exercise of which […] constitutes the most flourishing state of health, the slightest derangement of which is itself a disease, and of which the entire cessation is the extreme diametrically opposed to life, that is to say, death (Ménuret de Chamband, 2017, p. 360).

Breuer described a hypothetical principle for a self-organizing system – a regulation apparatus – that acted similarly to vital forces. The regulator is intentional (teleological), an organizer, acting according to a pre-established plan. Along the remainder of the chapter, Breuer's arguments departed from the assumption that the psychic apparatus is self-correcting and stable so that even psychic traumas undergo a process of ‘wearing-away’ (Breuer, 1895, p.291) merely as a result of time and an internal tendency of the body. The aim of the chapter was in fact to delineate the special circumstances that may lead this self-regulating mechanism to go astray. He articulated this model of the psychic economy through notions borrowed from Gustav Fechner, in particular his principles of constancy and pleasure (Fechner, 1873). Along those lines, Breuer conjectured a ‘principle of constancy of excitation’ that, when increased, would automatically seek discharge, and is experienced by the subject as unpleasant (Breuer, 1895, p.275). According to the principle, when excitation increases above the mean and is inhibited rather than being put into purposeful work, apparently purposeless substitutive acts may replace it – he provided the example of a patient contracting the arms of the dentist’s chair rather than pushing the doctor away while having a tooth extracted. This substitutive act, while apparently purposeless in not addressing the source of the pain, is still purposeful from the organism's perspective as it discharges the affect generated by the arousal.

In some cases, however, the heightened affect finds no form of discharge. In normal situations, Breuer maintained, the arousal gradually stabilizes over time. But in special circumstances, it can be converted into hysterical symptoms. These special circumstances, he explained, are created when the excitation is too high to be handled by the nervous system, or due to a weakness in the resistances to excitations – which Breuer, in turn, posited can be generated by an inherent predisposition, by states of excitation of long duration (such as the convalescence and death of her father in the case of Anna O.), or by weaknesses generated by illness. The conversion into symptoms generally follows the ‘path of least resistance,’ that is, by following the path in which resistances have been weakened the most. Along those lines, someone already suffering from heart problems is likely to have this increased by affections, or someone suffering from leg pain may experience paralysis, etc.

In a more interesting set of cases, the symptom may instead be formed via an ‘association by simultaneity’ (ibid., p. 285). If the original heightened experience of undischarged excitation is accompanied by a vivid sensory impression, thus creating an association between these events, when the affect is repeated it may bring up the impression once more – this time not as a recollection but as a hallucination. In this case, he said, we have a ‘facilitation of abnormal reflexes in accordance with the general laws of association’ (ibid.), which governs not only psychopathological states but all of mental life. Associations may be established not only amongst affective and sensory impressions but also between ideas. The symptoms in these extraordinary cases are ‘determined through symbolism,’ so that ‘what unites affect and its reflex is often a ridiculous play on words or associations by sound’ (ibid., p.203).

In a letter to Breuer from 1892, written with the purpose of outlining the central content of the *Preliminary Communication*, Freud described as central the ‘theorem concerning the constancy of the sum of excitation’ (Freud, 1940, p. 146). In the draft composed by Freud, at the end of that year, he again emphasized that ‘[t]he nervous system endeavours to keep constant something in its functional relations that we may describe as the “sum of excitation”’ (ibid., p.152). In an 1893 lecture, Freud once again postulated that ‘in every individual there exists a tendency to diminish this sum of excitation once more, in order to preserve his health’ (Freud, 1893, p. 35). The final version of the *Communication*, however, contained neither the principle of constancy nor the notion of the sum of excitation. This is probably the result of a disagreement between the authors and it would be fair to see the *Preliminary Communication* as ‘a kind of minimal consensus where Breuer clearly played a large part in dictating the limits to what he was willing to accept’ (Hirschmüller, 1989, p. 154).

While Breuer, in his “Theoretical” chapter, formulated his constancy principle around the idea of equilibrium and regulation, similarly to how he had previously treated the topics of thermoregulation, regulation of breathing, and regulation of bodily balance in his work as a physiologist, Freud, on the other hand, would formulate it around the notion of a “null principle” or “principle of neuronal inertia” (Freud, 1895). Whereas Breuer's model established that the nervous system must be in a constant mean state of tension, since low tension characterizes in his view states of low brain activity, as those present in dreamless sleep, and that it is the disturbance of this equilibrium that under certain circumstances can become traumatic or pathological, Freud understood the principle as stating that its purpose was to keep the levels of neuronal excitation at a minimal.

The difference between the two is most likely the result of different views on the philosophy of science and on the goals of scientific explanation. If Breuer, on the one hand, used the language of organic physics, on the other hand, he apologized to the reader for this strategy. His use of this terminology, he suggested, is analogical: ‘I shall scarcely be suspected of identifying nervous excitation with electricity, if I return once more to the comparison with an electrical system’ (Breuer, 1895, p. 202). At another point in the text, he wrote: ‘I am anxious not to drive the analogy with an electrical system to death. In view of the totally dissimilar conditions it can scarcely illustrate the processes in the nervous system, and can certainly not explain them’ (ibid., p.206 n.1). As Hirschmüller argued, remarks like these show that Breuer understood the analogies with electricity merely as helpful structural devices, and largely aligned with Machian empiricism: ‘they are pictures he borrowed from the conceptual vocabulary at his disposal. He is far away from identifying the pictures with the actual state of circumstances’ (Hirschmüller, 1989, p. 163). As Breuer would tell Brentano some years later, ‘I do not think that energy must be thought of as a real substance, or that it can be so conceived’ (Breuer, [1903] 1989, D10). He nevertheless still considered his economic model a heuristically useful framework to account for both brain function and psychopathology.

Despite treating the model in a language characteristic of organic physics, Breuer made it clear that its use is merely analogical. And as previously seen, his model of psychic economy arguably bears greater a resemblance to a form of vitalism than to Exner's mechanism. This did not go unnoticed by Breuer himself. He discussed his views on teleology and vital forces in at least three writings. In 1902, he gave a lecture to the Vienna Philosophical Society titled *Die Krisis der Darwinismus und die Teleologie* [The Crisis of Darwinism and Teleology] (Breuer, 1902/1986), where he advocated a type of epistemic teleology for the explanation of vital phenomena. This lecture, in turn, motivated a brief correspondence with philosopher Franz Brentano the following year (Breuer, 1989a, 1989b, 1989c), where he extended his argument. For our purposes, however, it is most relevant that we deal with his correspondence with philosopher Theodor Gomperz, since it took place in 1895, the year he wrote his “Theoretical” chapter for *Studies on Hysteria*.

In the first of his three letters to Gomperz (Breuer, 1989d), Breuer defended a form of vitalism against the ‘physicalism’ of du-Bois Reymond. The letter is fundamentally a critical commentary evoked by his reading of du Bois' lecture *Über Neo-Vitalismus* [On Neo-Vitalism] (du Bois-Reymond, 1894), of which Gomperz had lent him a copy. In his characteristic style, du Bois opened the lecture by presenting an historico-critical view of the concept of vital force, whose existence, according to him, ‘was seen as a being related to the soul and living in the body. On the other hand, the concept was often intermingled with that of the so-called nervous principle, or even animal warmth, and later electricity galvanic process’ (ibid., p. 2). Du Bois presented his historical reading of the development of the notion of vital force, from Aristotle's *Entelechy* to Barthez's *Principe Vital* and its subsequent transformation during the nineteenth century into that of *Lebenskraft* by J. Reil, J. Blumenbach and J. Müller, for whom:

> …the vital force was the unifying cause and the highest order of all phenomena of life, and essentially different from the inorganic forces with which it is, however, in conflict. All the secrets of physics and chemistry were revealed to it from the beginning, so that it could cope with the miracle-building of the instruments of sense and movement, of the apparatus of breathing and digestion – in a word, of organization (ibid., p. 3-4).

Du Bois's argument in the lecture was not new, and in general terms repeated what he had proposed in his famous "Preface" to *Untersuchungen über tierische Elektricität* [Investigations into Animal Electricity] (1848), a text that was seen at the time of its publication as a manifesto of the organic physics group, and later published separately under the title *Über die Lebenskraft* [On Vital Force]. In the 1894 lecture, he focused his argument, as he had done in the past, on a critique of the notion of force: ‘Force is nothing real, as vitalism thinks it, it is not a being combined with the material substratum, constituting matter as it appears to our senses, and which can also stand apart independently of matter’ (du Bois-Reymond, 1894, p. 6).

In his letter, Breuer agreed with du Bois' objections to the notion of force. He argued that the concept was an outdated term that still heavily carried notions of substance and anthropomorphism. Breuer however considered the issue a mere ‘quibbling over words’ (Breuer, 1989d, p. 223) that did not address the core of the matter. The notion of vital force should not be abandoned altogether, he maintained, but instead be replaced ‘by another term which inventive imagination is well able to provide along the lines of gravitation, electricity and magnetism’ (ibid.). He further noted that the notion of force had been progressively replaced by that of energy and that treating vital force as a form of energy could make it mathematically tractable. The parallel between these statements to his chapter in *Studies on Hysteria* where, as we have seen, he developed a speculative description of brain function based on the notion of latent and kinetic energies, is clear. As the letter tells us, these concepts serve as substitutes for the notion of vital force. Whether we call it force or energy, in this sense, is merely a ‘quibbling over words’ that does not address the core of the matter.

Breuer brought a compelling analogy to illustrate his argument: if ancient physicists, who only possessed the knowledge of mechanics, were confronted with the phenomena of electricity, they would be justified in attempting to explain it in mechanical terms. Their failure to do so would also justify their critics, who would in turn declare these phenomena to lie in some other force beyond the known bounds of physics. ‘Similarly’, he said, ‘vitalism rejects the idea that inorganic forms of energy and motion can ever be sufficient for an explanation of life’ (ibid.).

In his "Preface", Du Bois had claimed that the iron atom is subject to the same laws, whether it is flying through space in a meteorite or in the bloodstream in a philosopher's head – an argument he repeated in the lecture. Breuer saw two possible ways of interpreting this statement. If du Bois argued that an atom does not change its properties upon entering a living organism, he was merely ‘putting forward self-evident truths’ (ibid., p. 224). If, however, he argued that the set of physical laws by which the atom operates with its surroundings is the same:

> That is precisely what we do not believe. We believe that the laws it obeys as a component of living material and drifting in the stream of vital motion are not the same as those we find in the meteorite […] The laws which this much-tormented iron atom obeys when it is a particle in a meteorite are different again to those which govern it when it is influenced by a magnetic field here on Earth (ibid., p.223).

Breuer contended that organisms in this sense operate under different physical laws, and acknowledged: ‘*that is why we are vitalists’* (ibid., p. 225, my italics). He, therefore, self-identified as a (neo-) vitalist, by which he understood that the phenomena of life ultimately break with a mechanical approach to nature and that its explanation lies beyond the regions then accessible to physics and chemistry – particularly if these are reduced to analytical mechanics. The reason for the rupture lies in the teleological features of the organic realm, which had been obliterated by the organic physics group.

‘The physicalist school,’ he concluded, ‘have no more investigated the essence of life than Columbus explored the coast of Japan’ (ibid., p.224).

Nervous Energy and Medical Practice

Despite some significant personal differences, amongst which their socio-economic and religious backgrounds, Josef Breuer and Sigmund Exner also shared great resemblances. Both grew up in Vienna in the second half of the nineteenth century and studied medicine in the same institution at a time when its approach to physiology had become synonymous with organic physics. They had established research careers in physiology, and vast experience in both experimental and observational methods, before engaging in research topics that lied at the frontier with psychology. They were intimately familiar with each other’s works, shared largely the same social circles, participated in many of the same *Vereine*, and had access to (and referenced) fundamentally the same scientific and philosophical references. They also shared similar liberal political and world views, as well as analogous aesthetic values. Such similarities were transformed into a lifelong friendship, which was also extended to their families (cf. Hirschmüller, 1989; Coen, 2007).

What therefore explains the widely different approaches and conclusions to otherwise such similar works and authors? Although no single factor is sufficient for a complete explanation of their differences, one prominent element is the role played by medical practice in theory construction. While Exner formulated the model articulated in *Entwurf* exclusively within the Institute of Physiology, Breuer was actively engaged in clinical work in both hospital settings and private practice. The need to formulate a model that accounted not only for how a brain functions, but also how it “malfunctions” – as well as for explaining the mechanism of his proposed therapeutic method – meant he was unavoidably forced to treat topics for the most part absent in Exner’s account. This difference in focus is also largely derived from the attitude towards medical practice they learned in their respective training. Exner had been Brücke’s prime pupil and was also strongly influenced by Meynert. Breuer in turn had for many years served as an assistant to Johann Oppolzer,[16] the professional in whom he ‘found his ideal’ (Hirschmüller, 1989, p. 19). Chair of internal medicine of the Second Clinic, Oppolzer promoted an active approach to medical treatment and openly criticised the therapeutic scepticism and pessimism prevalent in the medical school at the time (Johnston, 1972, p. 223ff.; Lesky, 1976, p. 126ff.; Luprecht, 1991) – of which Brücke and Meynert represented prominent cases.

[16] It is not clear when Breuer started working with Oppolzer. In 1867 he was hired as an assistant in the post previously held by Johann Schnitzler (Arthur Schnitzler’s father), a position he held until Oppolzer’s death in 1871. It is probable however that he had already previously worked as an *Aspirant* in the clinic in the mid-1860’s (Hirschmüller, 1989, p. 20).

In his writings, Breuer rejected dualism and defended a form of monism and identity theory. He did not however articulate his views on the nature of the mind as unambiguously as Exner. On the one hand, as Breuer contended, his experience with neurological cases made him 'daily and hourly witness to how completely every psychic event is a function of states of the cerebral cortex' (Breuer, 1989b, p. 238), which made it 'most reasonable to assume their identity' (Breuer, 1989c, p. 252). On the other hand, the 'heterogeneity' between psychic and physical phenomena makes 'monism seem to me quite impossible'. The impact of his concern with understanding and treating psychopathological phenomena, and particularly hysteria – a psychogenic disorder that generated bodily symptoms, and that could be treated by psychological methods (such as suggestion, hypnosis, and the cathartic method) – was certainly a key factor in his scepticism towards theories that "explained away" the mind. Breuer's philosophy of science allowed him to suspend his scepticism in monism and accept it on the basis that 'we in the natural sciences are well used to adopting the essential contents of a hypothesis […] even when it is incapable of explaining everything when it leaves the most important details unexplained, and even when in its present formulation it contains clear contradictions' (ibid., p.252).

Regarding their uses of energetic formulations, while Exner made use of the framework in order to bring the burgeoning field of neurophysiology in line with the precepts of organic physics, thereby removing any vestiges of the concept of vital force in his science, Breuer, in turn, defended a form of vitalism and used the notions of free energy and excitation as replacements of vital force 'by another term which inventive imagination is well able to provide along the lines of gravitation, electricity and magnetism' (Breuer, 1989d, p. 222). The key difference here may once again lie in the place of medical practice in theory construction. As Elizabeth Williams argued in her cultural history of Montpellier vitalism, one central element that differentiated the teaching in the school had been its emphasis on practical and clinical work, which was likely informed by the provincial character of the relatively small town – contrasting with larger medical centres like Paris, whose approach at the time was synonymous with Cartesian medical mechanism. This emphasis contributed to a focus on the singularity of the patient rather than on general categories of medical theory (Williams, 2003, p. 16ff.). A similar argument can be made of Breuer. As he noted in one of his letters to Brentano, considering that 'every intellect is determined […] by the circumstances and occupations of its period of development' (Breuer, 1989b, p. 239), his was one determined by his medical practice since 'I am not a mere clinical professor but also the doctor trying to save his patient' (ibid., p.246). His training with Oppolzer and focus on medical practice led to a rejection of wide-ranging generalizations and dogmatism, and thus to a position generally in agreement with Machian critical empiricism. Despite believing that monism is ultimately contradictory, or that energy cannot be thought of as a real substance, or even that his electrical analogies faithfully represented the reality of brain processes, he nevertheless still considered his economic model a heuristically useful – albeit temporary – framework to account for both brain function and psychopathology.

Exner never completed *Entwurf*. The published version indicates it was intended as the first part of a larger piece of work, but we do not know how many volumes he had envisioned, nor their contents. Considering his extensive prior work on the topic of cerebral localisation, based on 'observation at the bedside' of neuropathological cases, and summarised in the monograph *Untersuchungen über die Localisation der Functionen in der Grosshirnrinde des Menschen* [Investigations on the localisation of functions in the human cortex], the absence of clinical topics is revealing. There, he had claimed that '[p]hysiology is regarded, and rightly so, as a cornerstone of pathology. Movements which take place in the former penetrate also into the region of the latter. But physiology has always been in close contact with the clinical sciences, and in relation to one of its branches it must be taught directly to them. I mean the physiology of the central nervous system' (Exner, 1881, p. v). It is therefore possible, albeit speculative, that Exner might have intended on covering neuro- and psychopathology in subsequent volumes of *Entwurf* since he fleetingly touched on such topics (Exner, 1894, p. 155, p. 269). In *Untersuchungen*, Exner only described the clinical effects of brain damage and used statistical methods to establish correlations between the site of lesion and mental functions. In *Entwurf*, however, he would have to explain the mechanisms of the formation of pathological phenomena – a challenge that may have proved to be the ultimate obstacle to his mechanical model.

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