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Mechanism, Life and Mind in Modern Natural Philosophy

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Editors
Charles T. Wolfe
Département de philosophie
Université Toulouse 2 Jean-Jaurès
Toulouse, France

Paolo Pecere
Department of Philosophy
Università di Roma Tre
Rome, Italy

Antonio Clericuzio
Department of Humanities
Università di Roma Tre
Rome, Italy

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Contributors

Raphaële Andrault CNRS IHRIM-ENS de Lyon, Lyon, France

Andreas Blank Alpen-Adria Universität Klagenfurt, Klagenfurt, Austria

Cécilia Bognon-Küss Laboatoire Épigénétique et destin cellulaire, UMR 7216, Université Paris Diderot, Paris, France

Matteo Favaretti Camposampiero Ca' Foscari University of Venice, Venice, Italy

Riccardo Chiaradonna University of Roma Tre, Rome, Italy

Antonio Clericuzio University of Roma Tre, Rome, Italy

Guido Giglioni Dipartimento di Studi Umanistici, Università di Macerata, Macerata, Italy

Oana Matei Vasile Goldiș Western University of Arad, Romania, Arad, Romania
University of Bucharest, Bucharest, Romania

Antonio M. Nunziante University of Padua, Padua, Italy

Lydia Patton Virginia Tech, Blacksburg, VA, USA

Paolo Pecere University of Roma Tre, Rome, Italy

Ursula Renz University of Graz, Graz, Austria

Emanuela Scribano Ca' Foscari University of Venice, Venice, Italy

Marco Storni University of Neuchâtel, Neuchâtel, Switzerland

Luca Tonetti University of Bologna, Bologna, Italy

Charles T. Wolfe Département de philosophie & ERRAPHIS, Université de Toulouse Jean-Jaurès, Toulouse, France

Chapter 18
Organic Memory and the Perils of Perigenesis: The Helmholtz-Hering Debate

Lydia Patton

Abstract This paper will focus on a famous nineteenth century debate over the physiology of perception between Ewald Hering and Hermann von Helmholtz. This debate is often explained as a contest between empiricism (Helmholtz) and nativism (Hering) about perception. I will argue that this is only part of the picture. Hering was a pioneer of Lamarckian explanations, arguing for an early version of the biogenetic law. Hering explains physical processes, including perception, in terms of 'organic memory' that is supported by 'vital forces' located throughout the body. Helmholtz, on the other hand, argues that vital forces are in direct conflict with the results he and others proved in the 1840s and 50s on the conservation of force. The battleground of the debate was the interpretation of Johannes Müller's 'law of specific nerve energies', which Hering interpreted in terms of vital forces, and Helmholtz interpreted using a naturalized neo-Kantian approach. In the end, the debate revealed deep fissures in nineteenth century accounts of scientific explanation, as well as in the conception of how physiology, psychology, physics, and philosophy are related.

18.1 Introduction

Two giants of nineteenth century science, Ewald Hering (1834–1918) and Hermann von Helmholtz (1821–1894), engaged in a well known debate over the physiology of perception and its effects on perceptual phenomena.[1] The debate between Hering

[1] The classic analysis is found in Turner 1994. Turner's work is the source of my own interest in the vitalist background to the debate. See Cahan 1993; Sherman 1981; Sulloway 1992.

L. Patton (✉)
Virginia Tech, Blacksburg, VA, USA
e-mail: critique@vt.edu

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and Helmholtz often is described as a dispute between empiricism and nativism. According to this account, Helmholtz did not want to employ innate structures in his explanations of physical and physiological processes, and instead argued that sense nerves provide us with bare signals that we must interpret, using inductive inferences from past experience to construct present experience. Hering, on the other hand, argued that perceptual phenomena such as binocular vision and simultaneous contrast are explicable by appeal to innate structures in the brain and nervous system. Thus, phenomena that Hering explains using innate structures (nativism) are explained by Helmholtz using inductive inference from previous experience (empiricism).

What follows is an account of why this is only part of the picture of the Hering-Helmholtz debate. Ewald Hering was a pioneer of Lamarckian explanations, arguing for an ancestor of the biogenetic law that ontogeny recapitulates phylogeny. Hering's approach united Lamarckian 'organic memory' with the hypothesis of perigenesis. According to his account, organisms inherit abilities and responses to stimuli, not just traits, and that they do so via species memory that is passed on to them via force or energy. Hering appealed to 'vital forces' to explain the processes taking place in "organized matter" (living beings).

Helmholtz, on the other hand, was committed from early on to the view that all physical processes must be describable and explainable using conservative force laws (Helmholtz 1853/1847). He saw vitalist explanations as in conflict with the conservation of force, especially with the impossibility of perpetual motion and the impossibility of an inexhaustible source of motive force.

In the case of the physiology of perception, the debate centered around the role of Johannes Müller's doctrine of specific nerve energies.[2] Hering explained the "specific energy" of each nerve in terms of his overall account using vital forces. Helmholtz resisted this interpretation of Müller's law, on the grounds that it was in conflict with the conservation of force. He argued for a rival explanation along naturalized, neo-Kantian lines.

In what follows, I will present Hering's Lamarckian account of perception, followed by Helmholtz's general theory of the conservation of force. These met on the battleground of the law of specific nerve energies. The conclusion will demonstrate how this debate reveals deep fissures in nineteenth century accounts of scientific explanation, as well as in the conception of how physiology, psychology, physics, and philosophy are related.

[2] Sometimes called the 'law of specific sense energies'. It is referred to, quite confusingly, as the "Gesetz der spezifische Nervenenergien" *and* as the "Gesetz der spezifische Sinnesenergien" in this tradition.

18.2 Hering on Organic Memory and Vital Force

Ewald Hering (1834–1918) was an influential physiologist. "In 1865, [he] succeeded Carl Ludwig as professor of physiology at the Josephinum, a military medical school in Vienna that was separate from the university, and in 1869 succeeded Jan Purkinje as professor of physiology in Prague" (Bosmia et al. 2016, 1561). Hering is well known for his work in the physiology of perception, and for his debates with Hermann von Helmholtz.

It is no less notable, however, that Hering was a very influential defender of a Lamarckian approach to ontogeny,[3] and of vitalism or hylozoism more generally.[4] On May 30, 1870, Hering gave an address, "Memory as a General Function of Organised Matter", before the Imperial Academy of Sciences in Vienna. Hering's address was a forceful intervention in then-current debates over the heritability of organic functions.

Darwin had proposed "the hypothesis of Pangenesis, which implies that the whole organisation, in the sense of every separate atom or unit, reproduces itself. Hence ovules and pollen grains, – the fertilised seed or egg, as well as buds, – include and consist of a multitude of germs thrown off from each separate atom of the organism" (Darwin 1868, vol. II, 429). Living cells, before senescence, throw off 'gemmules' or particles that develop into gemmules similar to the particles of the body from which they are derived. As Winther (2000) observes, "The reproductive organs collected these gemmules to form the sperm or the egg. The development of an organism depended on the union of the inherited gemmules, from various life stages of the parent, with developing cells or gemmules in the organism's body" (pp. 444–5).

In his 1870 address, Hering defended the "organic memory" theory, a rival, Lamarckian explanation of why organisms seem to inherit instincts and abilities, as well as traits. According to this theory, organisms' reactions to irritation[5] become reinforced by constant repetition as stimuli are repeated. Long practice reinforces these mechanisms, which are "a series of phases" (p. 21) which then are transmitted via "germs" (p. 20). The theory is well described by Stephen Jay Gould:

> the acquisition of a character is like learning; … inheritance is like memory (learning is retained through memory; memory is enhanced by constant repetition over long periods; actions invoked at first by conscious thought become automatic when repeated often enough). Instincts are the conscious remembrance of things learned so strongly, impressed so indelibly into memory, that the germ cells themselves are affected and pass the trait to future generations. If behavior can be first learned and then inherited as instinct, then mor-

[3] Loosely, the growth and development of organisms – and, sometimes, how it is related to inheritance.

[4] See Normandin and Wolfe 2013, Steigerwald 2019, Zammito 2017, and Gambarotto 2018 for vitalism in nineteenth century philosophy. Giglioni 2013 argues that "hylozoism" is a more appropriate term than "vitalism", but since Helmholtz and Hering use 'vitalism' and 'vital force', I will use their actor's categories.

[5] For Lamarck's account of "irritability" and "sensibility" see Giglioni 2013.

> phological features might be acquired and inherited in an analogous way. Thus, ontogeny is the sequential unfolding of characters in the order of their phyletic acquisition: it is the organism's memory (Gould 1977, 96).

Ernst Haeckel and Samuel Butler, inspired by Hering, developed the hypothesis of "perigenesis" in response to Darwin's pangenesis.[6] Perigenesis is the "preference for the transmission of energy, rather than physical particles, from modified soma to the germ" (Gould 1977, 97).

The physiologist Edwin Ray Lankester was in the audience of Hering's talk. As he notes, a question immediately arose in discussions of perigenesis: "How are we to conceive of the propagation of such states of force-affection or vibration… through the organism from unit to unit? In what manner, again, are we to express the dormancy of the pangenetic gemmules in terms of molecular vibration?" (Lankester 1876, 236). Hering had one of the most popular answers to this question, arguing that

> since all transmission of "qualities" from cell to cell in the growth and repair of one and the same organ, or from parent to offspring, is a transmission of vibrations or affections of material particles, whether these qualities manifest themselves as form, or as a facility for entering upon a given series of vibrations, we may speak of all such phenomena as "memory," whether it be the conscious memory exhibited by the nerve-cells of the brain or the unconscious memory we call habit, or the inherited memory we call instinct; or whether again it be the reproduction of parental form and minute structure. All equally may be called "the memory of living matter." From the earliest existence of protoplasm to the present day, the memory of living matter is continuous (Lankester 1876, 237).

Hering's theory is one of the origins of the biogenetic law, that ontogeny recapitulates phylogeny, and it is recognized as such by Gould's classic study of the law (1977, 96–7). As Hering wrote,

> Every organic being which lives to-day, is the latest link of an immeasurable series of organic beings, of which one rose into existence from the other, and one inherited part of the acquired properties of the other. The whole history of individual development, as observed in higher organised animals, is, from this point of view, a continuous chain of reminiscences of the evolution of all the beings which form the ancestral series of the animal. A complicated perception takes place by means of a volatile, and, as it were, superficial reproduction of cerebral processes which have been long and carefully practised; exactly so a growing germ passes quickly and summarily through a series of phases which were developed and fixed, step by step, in the memory of organised matter in the series of its ancestral beings, during a life of incalculable duration (Hering 1870/1897, 20–21).

The hypothesis of perigenesis, picked up by Haeckel in his piquantly titled *The Perigenesis of Plastidules* (1876), has it that an organism's development and abilities recapitulate the history of its ancestors, and that the seeds of those abilities are

[6] Hering's 1870 speech influenced Samuel Butler (Turbil 2018, 8), Ernst Haeckel (Lankester 1876, 237; Haeckel 1876, 40–41), Edward Drinker Cope, and Alpheus Hyatt. See Pearce 2018 and Gould 1977, 97 and *passim*, for discussions of Haeckel, Cope, and Hyatt. Forsdyke (2015) argues that Schrödinger "repeatedly cited the *Mneme* books of Richard Semon, who had studied with Haeckel in Jena…. We can now trace the path of fundamental informational ideas – oscillating between German and English – from Hering/Butler to Semon, to Schrödinger, and then on to Francis Crick and others" (Forsdyke 2015, 276).

found in transfers of energy or "force-affection" from parents to offspring. Within the particular organs and structures of all living beings can be found the vital forces that allow for inherited abilities; forces that underwrite the expression of abilities ingrained in the organism's ancestors through repeated practice and memory. The metaphor of "memory" thus has two sides: First, an organism can remember how to do something it has done before. Second, because of the biogenetic law, organisms "remember" abilities that they have never before put into practice.

Hering's pioneering defense of perigenesis is the foundation of his account of perception, and the latter can't be understood independently of the former. When Hering explains perception using "innate" features, he is not appealing to innate structural features of human physiology. Instead, Hering is appealing to "organic memory": an inborn "series of phases" or sequences of actions that an organism consciously or unconsciously performs when presented with a stimulus. The "memory" in this case is not a conscious recalling to mind, but a response to a repeated stimulus that's become ingrained in the organism, or inherited via transfers of "qualities" or "vibrations" from its ancestors.

> A chick which creeps out of its shell at once runs about... Think how extraordinarily complicated are the motions and sensations of such acts! Only consider the difficulty involved in the equipoising of its body in running, and it will be conceded that the supposition of an innate reproductive faculty alone, can serve as an explanation… The chick is not only endowed with an inborn skill over its motions, but possesses, also, a strongly developed perceptive faculty. Without hesitation it picks up the grains which are thrown to it… Such a feeble irritation as the rays produce which proceed from a grain and fall upon the retina of the chicken form the occasion of the reproduction of a complicated series of sensations, perceptions, and motions, which in this individual have never as yet been combined, and which, nevertheless, from the beginning were adjusted with accuracy and precision, as if the animal itself had practised them thousands of times (Hering 1870/1897, 21–2).

By Hering's own lights, his account is an attempt at a *physical* theory that accounts for all the phenomena using what he understands as *empirical* explanations. He appeals to acquired abilities and traits, extending the Lamarckian theory of evolution into a theory of organic memory and hypothesis of perigenesis.

> Such surprising performances of animals are generally called instincts; and some philosophers have indulged in mystic explanations of instincts. If instinct is regarded as the result of memory, or of the reproductive faculty of organised matter, if we assume that also the race is endowed with memory, instinct is understood at once; and the physiologist is enabled to correlate and connect instinct with the great series of facts found to be phenomena of the reproductive faculty, in this way we have not yet gained, but we have certainly approached, a physical explanation of the problem (Hering 1870/1897, 22–23).

Hering's theory of perception unites these elements into a single explanation, appealing to what he saw as empirical and physical features. As a newborn chick is able to perceive the grain of corn thrown to her, so a human child is able to achieve perceptual competence surprisingly quickly. For instance, Hering explains binocular vision as an inherited ability, supported by the long practice of human ancestors and passed down to offspring.

Thus, Hering's account of the physiology of perception was not merely 'nativist', in the broad sense of 'appealing to inborn structures and processes in the

organism'. His explanation of those structures and processes goes well beyond that, drawing heavily on the account of Lamarckian organic memory via the hypothesis of perigenesis that Hering pioneered himself. Moreover, perigenesis for Hering was supported by vital forces associated with the different organic systems of the body, vital forces that direct the processes and functions of 'organized matter' (living bodies).

There are several red Herings in the debate between Helmholtz and Hering. The first is the idea that Hering was only a 'nativist' in the narrow sense above, and that Helmholtz therefore rejected all explanations via innate structures. A second misleading narrative is that Hering offended against Helmholtz's preference for materialist or naturalist explanations. To be sure, Hering argues that conscious phenomena are functionally correlated with material processes, and he argues against abolishing the phenomena of consciousness in favor of what was then called 'bare materialism'.[7] However, that was hardly an unpopular view at the time. For instance, Friedrich Albert Lange takes a similar (but distinct) position in the curious chapter "The Standpoint of the Ideal" in his magisterial *The History of Materialism*[8] – a book with which Helmholtz was very familiar, and which he admired.

As we will see, the dispute between Hering and Helmholtz did not turn on whether Hering's theory was sufficiently empirically well grounded, or with whether Hering appealed to idealist elements.[9] Instead, a central question at issue was about whether the phenomena of instinct, memory, learning, and unconscious inference in physiology required the hypothesis of perigenesis and of vital forces. Hering appealed to vital forces, but he saw these as physical. He argued that vital forces, guided by inherited organic memory, organize the material processes taking place in all living beings. In the following section, we will see why Helmholtz resisted Hering's conclusions.

18.3 Helmholtz on Living Force

In 1845, a small group of researchers formed the Berlin Physical Society, founded by the materialist Emil du Bois-Reymond, which met at the house of Gustav Magnus, a physicist, and came to include Werner von Siemens. Du Bois-Reymond formed the group with the explicit goal of banishing vitalism, the postulate of vital forces in addition to material or mechanical forces, from science. These nineteenth century researchers investigating the physiology of perception were concerned with

[7] Hering 1870/1897, 2–6.

[8] See Edgar 2015.

[9] Helmholtz, unlike his friend du Bois-Reymond, was not hostile to these (De Kock 2015, Du Bois-Reymond 1872). See Finkelstein 2014 for du Bois-Reymond on consciousness.

the limits of materialist explanations, and with the character of perceptual experience and how it was related to physiological processes.[10]

Their research program is well characterized by du Bois-Reymond's 1872 address "Über die Grenzen des Naturerkennens," known as the Ignorabimus ("we will not know") lecture. There, du Bois-Reymond argued that in principle, most phenomena can be known by appeal to "atomic processes" and their evolution according to deterministic laws, using the methods Pierre-Simon de Laplace had made famous. There were only two exceptions: the "essence of matter" itself will never be known, and the phenomena of consciousness and how it arises from matter is also unknowable in the Laplacian sense (Finkelstein 2013, 265–266; du Bois-Reymond 1872).

Another member of the society was Hermann von Helmholtz, who, like du Bois-Reymond and Ernst Brücke, began his career as a student of the naturalist and Schellingian *Naturphilosoph* Johannes Müller.[11] One of Helmholtz's first papers, "On Metabolism during Muscular Activity" (1845), was an analysis of the heat produced by the muscles of frogs.

Helmholtz's paper would not have been possible without two significant factors. The first is the considerable progress in research on electricity in the late eighteenth and early nineteenth century, especially the research of Alessandro Volta and Luigi Galvani. Galvani had discovered that dead frogs' legs twitched when electricity was applied to them. Volta used the fact that frogs' legs can be used as conductors of electricity to construct experiments. Using these advances, Helmholtz was able to construct an empirical test of the claim that the phenomenon of heat generated by frogs' muscle twitches required extra-metabolic forces, a test that rejected that claim decisively.

The second factor is the tradition of mathematical analysis from the eighteenth century, including the work of Euler, Lagrange, D'Alembert, and Bernoulli, and that of analytical mechanics, including the work of Joule, Rumford, and others.[12] Their work made possible the precise calculation of forces and their contribution to particular actions. This was of particular interest to Helmholtz and du Bois-Reymond, as they had a common interest in showing how the forces of nature could be described using methods of mathematical physics (central forces, for Helmholtz; Laplacean determinism, for du Bois-Reymond).

One particular goal of this tradition was to refute the possibility of a perpetual motion machine, which will become very significant in the discussion of vital forces below. Vitalists used "vital forces" to explain how the processes within a living organism are organized or directed. These forces were postulated in addition to the specific processes within living bodies including metabolism and circulation.

[10] For the Berlin Physical Society see Wise 2018, Sulloway 1992, Finkelstein 2013, Turner 1994.

[11] For Helmholtz's relationship to Müller see De Kock (2015, 2019), Edgar 2015, and the above cited works on the Berlin Physical Society.

[12] See Schiemann 2008, Harman 1982, p. 61 and *passim.*

The work of Robert Meyer, James Joule, Helmholtz, and others on the conservation of force provided evidence against vitalist claims. Helmholtz's 1847 address on "The Conservation of Force" made a general argument that force (energy) is conserved in mechanical and dynamical cases.[13] Helmholtz's talk is often cited in the tradition of energy conservation laws, but it is important to note that he considered processes in living organisms to be occasioned by 'forces'. There were only 2 years between Helmholtz's paper on frog metabolism and his address on the conservation of force, and the two are intricately linked. In his 1845 paper, Helmholtz was able to demonstrate experimentally – and through quantitative measurement – that all the heat produced by frogs' muscles was produced by the frogs' metabolism. In that case, there was no need to appeal to a separate 'vital force' to explain the muscles' function.

Helmholtz 1847 address relies on the postulation of the law of causality. There, Helmholtz first defines the "comprehensibility of nature" as the possibility of finding the ultimate, invariable causes of natural processes. Then he introduces the two 'inseparable abstractions' of force and matter: matter being that which can only change by motion, and force the cause of motion. The comprehensibility of nature implies the reducibility of physics to forces that depend on the spatial configuration of matter only. Helmholtz goes on to apply the "decomposition principle" (Olivier Darrigol's term), according to which "the force which two whole masses exert on each other must be resolved into the forces which their parts exert on each other" (Helmholtz 1847, 15; Darrigol 2000, 215). In a fully comprehensible world, the resulting elementary forces are "central forces" acting between two mass points and tending to alter their distance at a rate depending only on the distance (Hyder 2009, ch. 3).

If we accept the principle of comprehensibility of nature, then physical forces are living, central forces. But we know that living central forces are conserved. By the comprehensibility principle, there are no other forces affecting the motion of matter. Thus, force is conserved overall.

Helmholtz also offers a proof that is not derived from the comprehensibility principle. The impossibility of perpetual motion (*perpetuum mobile*) has been demonstrated by the French tradition of analysis. If all physical forces are central forces, then for force not to be conserved would require a perpetual source of motion, which is not possible (Helmholtz 1847, 17–27).

> The law of the conservation of vis viva (living force) had been an established principle of mechanics for a century, its usage clearly distinct from the meaning of "force" as defined by Newton's laws of motion; and Helmholtz had enunciated his principle of the conservation of force as a generalisation of the principle of conservation of living force [vis viva] (Harman 1982, 60).[14]

As Caneva (2019) notes,

[13] See Caneva 2019, Hyder 2009, and Bevilacqua 1993.

[14] See Caneva 2019 for details on Helmholtz's law and vis viva.

> In the 1847 memoir itself Helmholtz gave pride of place to the impossibility of the unlimited creation of motive force (*Arbeitskraft*, *bewegende Kraft*, *mechanische Kraft*, or simply *Kraft*) from any combination of natural bodies (*Naturkörper*). In the paper's second sentence he announced that his derivations could be based either on this principle (*Satz*) or on the assumption that all actions in nature can be reduced to attractive and repulsive forces whose intensity depends only on the distance between the interacting points (p. 21).

The impossibility of the "unlimited creation of motive force" is a key result of the 1847 address from Helmholtz's point of view. He took this result to be fundamental, and it was at the core of his scientific reasoning. The result was of particular importance in Helmholtz's debates with vitalists. Of course, Helmholtz could not disprove the existence of vital forces with certainty. However, many uses of vital force in scientific explanation take vital forces to be sui generis: to be the *source*, not the result, of the organization of matter in living bodies.

Helmholtz's characteristic approach when arguing with vitalists was to appeal to his results concerning the conservation of force. Vitalist explanations were unacceptable to Helmholtz (and to du Bois-Reymond), for two reasons: first, the requirement of "the comprehensibility of nature" meant that one could not appeal to forces that (to their minds) come out of nowhere to explain living processes. Since the vital forces are not explained in terms of any more fundamental force, there is no scientific way to explain the origin of vital forces' motive power.

Second, vital forces appeal to an endless source of motive force, which is in contradiction with Helmholtz's firm belief in the impossibility of a perpetual motion machine. Theorists like Ewald Hering appeal, not just one source of perpetual motion and thus motive force, but thousands, located all over living bodies. This was anathema to Helmholtz's approach. If processes in living bodies are directed by millions of forces that have no traceable origin, then nature is incomprehensible,[15] which is in conflict with Helmholtz's deepest commitments about science itself.

18.4 The Law of Specific Nerve Energies as Battleground

Between 1833 and 1840, Johannes Müller published several volumes of his *Elements of Physiology* (*Handbuch der Physiologie des Menschen*). Müller's work was seminal for both Hering and Helmholtz.

Müller's law of specific nerve energies (which de Kock abbreviates as LoSNE) is based on Müller's more general assertion that "that which through the medium of our senses is actually perceived by the sensorium, is merely a property or change of condition of our nerves".[16] Sensations are propagations of a state in our nerves, and perception is the taking up of that state into consciousness. The LoSNE is usually

[15] That is, incomprehensible by Helmholtz's lights. His discussion of the comprehensibility of nature in the introduction of the 1847 address explains what this means.

[16] Müller 1842/1833–1840, 707. I am following the presentation of the LoSNE in de Kock 2019 which cites this passage from Müller and the one following.

considered to consist of Müller's assertion that "the nerves of each sense are capable of one determinate kind of sensation only."[17] As de Kock notes, the law had a 'radical' impact on epistemological reasoning about sensation and inferences from it.

> Müller systematically articulated his law through ten basic principles, supported mainly by introspection, self-experimentation, and experimental work done by others (e.g., Purkinje). Most generally, the law asserted that each sense has a particular mode of reactivity, or a specific nerve energy, that can be produced by different (internal or external) stimuli, and that conversely, one stimulus can cause a different sensation depending on the particular sensory organ involved. By assuming that the quality of sensation is determined primarily by the structure of our physiological apparatus rather than by the properties of external objects, the law entailed a radical discontinuity between sensations and their cause (internal or external).[18]

Müller had long been preoccupied with the fact that the same stimulus could result in distinct sensations, even before any inference from perception takes place. A fire is sensed as heat by the haptic nerves and as light by the optic nerve, but it is the same fire and thus the same stimulus. Müller reasoned that the difference between sensations of heat and of light, both of which are associated with the same fire, must be located in the sense nerve itself.[19] There can be no single relation between a sensation and its stimulus, and, in fact, no single, determinate relationship between a sensation and the object that is putatively its source can be given directly in sensation. Any relationship of representation, whereby our sensations are taken to indicate objects, must be inferred.

As de Kock notes, Müller's work occasioned a radical rethinking of the relationship between sensation and perception. Over the course of the nineteenth century, two rival interpretations of the law of specific nerve energies emerged. The first was Helmholtz's. The LoSNE was fundamental to Helmholtz's methods in his *Handbook of Physiological Optics,* where he discusses Hering, and *On the Sensations of Tone*. The second interpretation belongs to Hering. Hering's address "On Memory", discussed in detail above, is accompanied in many English publications by his essay "The Specific Energies of the Nervous System", where Hering also addresses Müller and Helmholtz head on.

Hering begins his essay by summing up what, to him, is the essence of Müller's view. Hering argues that the key feature of Müller's doctrine of specific nerve energies is his investigation of the "nature" of each "nerve-fibre", which should explain *why* "the nerves of the different sensory organs produce such various sensations" (Hering 1897, 32). It should not be assumed, Hering argues, that "the same kind of

[17] Müller 1842/1833–1840, xiv.

[18] De Kock 2019, n.p.

[19] As Hering (1897) writes, "when a ray of light enters the eye, it causes an irritation of the nervous fibres and of the cerebral cells; and thus we become conscious of the sensations of light and of color. If, now, these same rays, which, when entering the eye, produced the sensation of light, fall upon the skin of the hand, and there irritate the delicate rootlets of the sensory nerves, this irritation is transmitted through the nerves and the spinal cord to the brain, and instead of light we are conscious of warmth. How is it that the same external agent in one case produces light, and in the other warmth?" (p. 30).

irritation is transmitted in all fibres of the various nerves" (p. 32). Rather, a specific nerve energy is a particular vibration that is intrinsic to each nerve, and that is sustained by a vital force specific to that nerve-fibre.

Hering's account of Müller's LoSNE is so tightly linked with his doctrine of organic memory and perigenesis that it can't be understood in isolation from that doctrine. To Hering, a specific nerve energy is a subset of the vital forces that sustain organic memory.[20] Hering acknowledges that, in the "present state of science", the only way that we can learn about the specific energies of nerves (and organs) is to discover their functional correlations with conscious, physical brain processes.[21] However, to him, the only way to pursue Müller's research program properly is to search for an ultimate explanation of the "nature" and function of each sense nerve, an explanation grounded in organic memory and perigenesis. Each sense nerve is differentiated by its distinctive, inborn response to stimuli, a *remembered* response that is supported by vital forces directing the function of the nerve itself.

As should be clear from §3 above, Helmholtz could not approve of this account of Müller's doctrine of specific nerve energies. Helmholtz restates Müller's law of specific nerve energies by identifying what he calls the "quality sphere" of a nerve, namely, the range of possible qualities that can be sensed with that specific nerve. Quality spheres are specific to particular nerves.[22]

For Helmholtz, sensation presents us with indeterminate information. Bare or uninterpreted sensation consists of a set of electrical impulses sent along nerve fibers, which do not in themselves constitute determinate perceptions or representations. Sensation presents us with a stimulation of a nerve, which is like an "insulated telegraph wire." Sense-nerve fibers, for Helmholtz, carry signals independently of

[20] In the midst of his examination of the LoSNE, Hering repeats his account of organic memory and relates it to "specific" energies: "As we cannot at present solve the problem of the internal variation of the externally similar germ-substances, we must be satisfied with the statement that the germs of each animal species possess an inherent and innate faculty — viz., a specific energy, which directs its developments in a manner characteristic of this animal and of no other. Again, each single germ possesses an individual energy, which, in addition to the normal features of its species, secures an individual character to its future development" (Hering 1897, 37).

[21] "The specific energies of the living substance in the different organs are characterised by their chemical or physical functions; while in the present state of science the energies of the nervous substance can be recognised only by the different sensations which they produce in our consciousness. Our sensations and all the phenomena of consciousness are the psychological expressions of physiological processes or the irritations of our nerves, — especially of our brain. Vice versa, these irritations are the material expression of the processes in our soul. The soul does not move unless, simultaneously, the brain moves. Whenever the same sensation or the same thought recurs, a certain physical process which belongs to this special sensation or thought is repeated; for both are inseparably connected. They are conditioned by and productive of each other. Accordingly, from the course of our sensations we can draw inferences concerning the simultaneous and corresponding course of processes in the brain" (Hering 1870/1897, 38–9).

[22] "Physiological experience has found, as far as testing is possible, that through stimulation of each single sensory nerve fiber only those sensations can arise that belong to the quality sphere of each single specific sense, and that each stimulus, which in general can stimulate these nerve fibers, generates only sensations in these specific spheres" (Helmholtz 1867, 193).

any other nerves, and carry those signals to the brain. Helmholtz held on to a version of Müller's law, which he expresses as follows:

> the quality of sensible experience depends primarily on the specific constitution of the nerve apparatus, only secondarily on the constitution of the perceived object. Which sense's quality sphere an occurrent sensation belongs to does not depend on external objects, but exclusively on the type of nerve struck. Which particular sensation from the encountered quality sphere will be generated, this, above all, depends on the nature of the external object that stimulates the sensation (Helmholtz 1867, 194).

Helmholtz's reception of the LoSNE was largely epistemological, something that is likely grounded in his relationship with Kantian, neo-Kantian, and Fichtean accounts (see Pecere 2020; Edgar 2015; de Kock 2019). The LoSNE entails a break between sensation and the objects we represent to ourselves as the causes of those sensations. Helmholtz, unsurprisingly, saw Müller's account as raising questions similar to those raised by Kantian transcendental idealism: do the objects that cause our sensations have the same properties as those we perceive in experience? If not, what is the relationship between external objects and our internal representations of them? On what is the relation between sensation and its object based?

In keeping with his principle of the comprehensibility of nature, Helmholtz argues that we must take it as an a priori principle that external objects exist, and cause our sensations. In §26 of the final, "psychological" part of the *Physiological Optics*, Helmholtz explains that, since perceptions of external objects require our "psychischer Thätigkeit" or mental activity, such perceptions (*Wahrnehmungen*) are a form of representation (*Vorstellung*) (Helmholtz 1867, §26, 427). Perceptions, as representations, are distinct from sensations (*Empfindungen*). Any perception of an external object requires representation, which at the least requires positing an object as the cause of the perception (ibid.). In 1855, Helmholtz gave a Kant Memorial Lecture, "On Human Vision," in which, as Hatfield has observed, Helmholtz argues that representation of objects in space requires "our positing objects as the causes of our sensations, and we make such posits in accordance with the proposition, 'no effect without a cause'".[23] Helmholtz explains responses to sensory stimuli in real time, for instance, as straightforward causal interactions between stimuli and our sense nerves. And he does think there is a way, at least in principle, to describe stimulus-response relationships accurately.[24]

Thus, it is not the case that Helmholtz rejects 'nativist' explanations out of hand: he does allow for accounts of perception and representation that appeal to organic, 'innate' structures, when accounting for the relationship between stimulus and response. In general, Helmholtz is interested in investigating the physiological basis of perception, much of which inevitably has to involve explanations using 'inborn' structures like the retina or optic nerve.

[23] Helmholtz 1855, 116; Hatfield 2011, §5, 329.

[24] As in Weber's and Fechner's approach using psychophysics, for instance. See Tracz 2018 for a reading of Helmholtz as a relationalist about perception in the contemporary sense.

However, Helmholtz rejects Hering's particular account, for reasons that are at times unfair, and at times reveal deep differences between their approaches. First, Helmholtz objects to Hering's view, not because Helmholtz objects to explanations using inborn organic structures of any kind, but because he rejects Hering's appeal to vital forces and organic memory. Given this, however, Helmholtz's account in the *Handbook of Physiological Optics,* if it is aimed at Hering, seems to be wrong-headed as a criticism of Hering's view.

> it can be quite difficult to judge what, in our intuitions achieved through the visual sense, is determined immediately through sensation, and what on the contrary is determined through experience and practice… Some tend to allow the influence of experience the widest latitude possible, and in particular to derive all spatial intuition from it; we can describe this view as the empiricist theories. Others indeed must allow the influence of experience for a certain class of perceptions, but believe they must presuppose for certain elementary intuitions that occur uniformly for all observers a system of innate intuitions not grounded on experience, namely spatial relationships. We may describe this latter view… as the nativist theory (PO 26: 435).

If – as is the case – Ewald Hering is to figure as a prominent nativist in Helmholtz's narrative, this is entirely unfair as a criticism of him. Hering did not argue for "a system of innate intuitions not grounded on experience". Instead, Hering argued that *all* intuitions are grounded in experience, namely, in organic memory. Hering's account includes *far more experience* than Helmholtz's does, as the experience and memory of an entire species is enformed into the development of each organism of that species.

A crucial insight that results from this comparison, though, is that Helmholtz focuses far more on psychological and physiological processes in the individual, in real time (what present-day physiologists call "occurrent" experience), than Hering does. Hering does not need to explain how a single individual organism learns to interpret her experience, or even to have that experience in the first place. Hering is aware that this is a deep problem (remember his example of the newborn chick), but his explanation of it appeals to that organism's inheritance of an acquired response, one acquired through the experience of distant ancestors. Helmholtz argues that the nativist position Hering defends does not properly account for the role of mental operation [*psychischer Thätigkeit*] in experience:

> the combination of sensations is maintained with the representation of their objects to seem so fixed and compulsive, to many physiologists and psychologists, that they are so little inclined to recognize that this combination rests on acquired experience and thus on mental operation [*psychischer Thätigkeit*], at least in large part, that they seek on the contrary a mechanical way that it takes place through pre-formed organic structures (PO 26:431).

Note that Helmholtz still does not seem to understand the exact basis of Hering's account (if Hering is in fact his target). Hering can appeal to inherited organic memory, not just "pre-formed organic structures". But one can understand why Helmholtz might see Hering's organic memory as a "mechanical way" that sensations are correlated with their objects. By Helmholtz's lights, a particular organism whose reactions to stimuli are directed by Hering's organic memory does not *learn* to interpret her sensations as depicting external objects. Instead, she carries out operations of

which she may have no conscious knowledge, operations her sensory organs have developed to carry out. Helmholtz does not make this point explicitly, but Hering's organic memory is not really memory for an individual: it is species memory. Thus, again by Helmholtz's lights, Hering's individual organism who is perceiving external objects doesn't really learn, or remember, anything when doing so. She merely repeats, 'mechanically', operations that are innate in her, 'pre-formed' in her 'organic structures' by the history of her species.

18.5 Coda: Helmholtz and Hering on the Unconscious

Helmholtz's criticisms of Hering, and vice versa, often miss their mark. It is hardly surprising. Helmholtz's intellectual formation took place in the Berlin Physical Society, in his training in physiology and physics, and in his reading of Kantian and neo-Kantian philosophy. Only in his relationship with Johannes Müller was he made aware of the details of vitalist explanations, along the lines of those Hering provides. However, at any time that Helmholtz was presented with vitalist explanations, he opposed them. Helmholtz thought vitalist explanations were in conflict with what he saw as a requirement for science: the comprehensibility of nature.

Hering, on the other hand, saw Helmholtz as a failed successor to Johannes Müller, a rightful place he claimed for himself (Hering 1897, 32–3).[25] Müller's program appealed to the 'natures' of sensory nerves and to the hylozoism Hering associated with Aristotle. But Helmholtz abandoned Müller's vitalism and his broader interpretation of specific nerve energies, to focus instead on individual experience, its limitations, and its conditions. We may find a source of this focus in Helmholtz's relationship with Kant and neo-Kantianism, or we may find it an indication of Helmholtz's empiricism (as he himself characterized it). Either way, Hering did not understand the motivation behind Helmholtz's methods.

Despite their mutual misunderstandings, Helmholtz and Hering are emblematic of rival nineteenth century approaches to the study of perception. Analyzing their relationship reveals a curious problem that looms unexpectedly large for both of them: the role of the unconscious in explaining perception.[26] Hering's Lamarckian approach was intended to show how physical processes in perception are correlated with conscious processes. But those conscious processes were undergirded, in Hering and in Lamarck, by unconscious ones. As Giglioni (2013) remarks,

> Lamarck considered orgasm,[27] irritability and sensibility to be forms of organic mutability through which organisms were able to modify and adjust themselves to a physical reality in continuous change without the need to invoke a pre-established harmony of divine origin or

[25] Which must have made it all the more galling that, for almost every academic position Hering ever took up, Helmholtz was offered that position first.

[26] It is very intriguing that Sigmund Freud got his start in the Berlin Physical Society (Sulloway 1992).

[27] Defined as "the first form of reactive energy through which living beings respond to the smallest influences coming from the outside" (Giglioni 2013, 26).

> to resort to animistic solutions… The ability to react in all its various forms – orgasm, irritability and sensibility – was seen as unconscious, that is to say, not based on the exercise of the will or on the knowledge of the function performed (p. 30).

In Hering's account based on organic memory, the 'unconscious' processes involved in perception are not intrinsically unconscious.[28] Rather, a tape that was recorded consciously is played unconsciously: the experience of an individual's ancestors is encoded into that individual's "memory", and it does not need to be brought to mind for the physiological process it engenders to take place. In the Lamarckian tradition, Hering does not require an individual to be conscious of her responses to stimuli, or of the physiological processes she carries out in order to perceive objects.

As we saw above in §4, Helmholtz criticizes 'nativists' for ignoring the place of active learning and inference from experience on the part of the individual subject. Nativists, to Helmholtz, do not recognize the importance of 'mental operations' in the construction of experience (de Kock 2014, 106). So, one might imagine that Helmholtz would reject with scorn any intrusion of unconscious processes into his explanation of perception. But that would be mistaken. In the 'psychological' section of the *Handbook of Physiological Optics*, Helmholtz put forth his well known – and infamous – theory of perception as involving 'unconscious inferences' from previous experience (Hatfield 1990, 167; Patton 2018, 104–107).

Helmholtz's unconscious inferences rather suspiciously resemble the unconscious operations of Hering's organic memory in perception. But Helmholtz thought there was a crucial difference: Helmholtz's unconscious inferences are psychological, not physiological. They are fixed features about the way "we achieve from the observed effect on our senses the representation of a cause of this effect" (PO 26: 430). This achieved representation, to Helmholtz, always involves mental operations, and is not an 'organic' process that takes place automatically. This is precisely the place in §26 where Helmholtz argues against 'nativist' explanations of unconscious inference.

Helmholtz argues that it is key to exclude unconscious inference from previous experience from physiological explanations. If we do so, he argues, we would lose sight of how mental processes make our representations possible, and thus would miss out on characterizing a key element of the epistemology of perception.

Note, then, that Helmholtz's account and Hering's account resemble each other quite closely, in some respects. Both rely on the acquisition of immense knowledge and ability from previous experience, knowledge and ability that has a profound and even unconscious effect on future experience. Both argue that perception cannot be explained by materialist, physical explanations alone, allowing for the contribution of psychological and physiological processes that are not solely material. Both defend an account of the contributions of 'unconscious' processes in perception and representation.

[28] Hering makes this point explicitly: "every organised being of our present time is the product of the unconscious memory of organised matter" (Hering 1870/1897, 20).

The differences are equally profound, but they boil down, as has been explained above, to a difference in fundamental explanation. Hering formulated a Lamarckian account using organic memory, which supports 'unconscious' perceptual processes engrained in the species and transmitted via inheritance, which required vital forces to support the processes in question. Helmholtz argued that vital forces contradict the law of conservation of force, and are in conflict with the comprehensibility of nature. To Helmholtz, Hering's account was not scientific. To Hering, Helmholtz did not provide a true explanation of *why* perceptual processes are the way they are – for instance, of the nature of the sense nerves and their role in the physiology of perception. They would never agree, but their disputes illuminate broad methods operating – perhaps even unconsciously – in nineteenth century science.

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Lydia Patton is a philosopher and historian of philosophy of science who focuses on theory change, theory assessment, and the relation between formal reasoning and evidence. She has written extensively on scientific and mathematical method, realism, naturalism, and apriorism,

including their histories in the Kantian tradition especially. Her work has appeared in journals including *Studies in History and Philosophy of Modern Physics*, *Synthese*, *The Monist*, *History and Philosophy of Logic*, and *Historia Mathematica,* and in dozens of edited collections. She is the editor of *HOPOS* and, with Walter Ott, of the collection *Laws of Nature*.