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The emergence of *Nervennahrung*: Nerves, mind and metabolism in the long eighteenth century

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Nerves, mind and metabolism in the long eighteenth century

Abstract: Morphological assumptions concerning the form, structure and internal life of the brain and nervous system profoundly influenced contemporary physiological concepts about nerve actions throughout the 'long eighteenth century'. This article investigates some early theories of mind and metabolism. In a bottom-up fashion, it asks how eighteenth-century theories regarding the physiological actions of the body organs shaped the conceptions of the structure of the brain and nervous tissue themselves. These proposed that a healthy *Nervennahrung* (the German word for 'nerve nutrition', which might be rendered as *brain food* in modern English), not only guaranteed the integrity and stability of neuronal structures in the body, but also explained the complex texture of the brain and spinal cord in physiological terms. Eighteenth-century nerve theories already embodied a *Leitmotiv* of neurology and brain psychiatry from the later nineteenth century: '*Without phosphorus there is no thought!*'

Key words [MeSH]: Nerve theories – History, eighteenth century – Brain anatomy – Neurophysiology – History of medicine – Mind – Nutrition

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Zusammenfassung: Morphologische Auffassungen zur Form, Struktur und den internen Vorgängen des Gehirns und des Nervensystems haben bereits im „langen achtzehnten Jahrhundert“ auf tiefgreifende Weise die zeitgenössischen physiologischen Konzeptionen über die allgemeinen Nerventätigkeiten beeinflußt. Der vorliegende Artikel untersucht einige dieser frühen Theorien über den Zusammenhang von Geist und Metabolismus. In induktiver Weise wird hierbei gefragt, wie genau die Theorien des achtzehnten Jahrhunderts über die physiologischen Tätigkeiten der Körperorgane die konzeptionellen Auffassungen über die Struktur von Gehirn und Nervengewebe mit bestimmt haben? So gingen etwa die zeitgenössischen Theorien davon aus, dass eine gesunde *Nervennahrung* (als früher deutschsprachiger Begriff für die moderne Auffassung von *brain food* – in Englischer Sprache) nicht nur die Integrität und Stabilität der neuronalen Strukturen des lebendigen Körpers aufrechterhielte, sondern dass ferner das Arrangement der komplexen anatomischen Struktur von Gehirn und Rückenmark selbst auf besondere Weise von den physiologischen Funktionsweisen abhänge. Die Nerventheorien des achtzehnten Jahrhunderts bereiteten somit bereits die theoretische Grundlage eines späteren, zentralen *Leitmotivs* von Neurologie und Gehirnpsychiatrie im ausgehenden neunzehnten Jahrhunderts vor: „*Ohne Phosphor kein Gedanke!*“

Schlüsselwörter [MeSH]: Nerventheorien – Geschichte, achtzehntes Jahrhundert – Anatomie, Gehirn – Neurophysiologie– Geist – Nahrung – Medizingeschichte

The emergence of *Nervennahrung*:

Nerves, mind and metabolism in the long eighteenth century

1. Introduction

A pivotal goal of the history of neuroscience should definitely be the mapping of the relationship between traditional concepts portraying the actions of the nerves and their underlying morphological and metabolic substrates. In the absence of such an analysis, we can scarcely develop a general sense of the multi-layered dimension of the structure-function relationship in the human nervous system, nor can we adequately reconstruct the crucial changes in discourses between the eighteenth and the early nineteenth century.[1] A number of historians of neuroscience have proposed that the discursive changes accomplished in the transition from the early modern period to the nineteenth century were distinct and clear cut transformations rather than complex mixes of approaches.[2] Moreover, it has been contended that no transitional terms arose between the seventeenth and eighteenth centuries, and the notion that earlier concepts might have taken on a life of their own has seemed unthinkable. Even the later 'elimination of concepts' dating from the early modern period has been interpreted as a consequence of the eighteenth-century empirical turn.[3] The standard view in the secondary literature is that nerve spirits gave way to nervous fluids, mechanical forces to electromechanical interactions, nerve fibres to brain functions, sensibility and irritability to nerve action, and vital forces to nutritive, later metabolic, processes.[4] However, I will argue in this article that there were a number of important parallel developments in contemporary neuroscientific theories. Concepts of nervous nutrition were supported by appeal to earlier traditions, so that animistic, mechanistic and even vitalist doctrines survived. The historian of physiology Michael

1 Cf. Rousseau (1973), pp. 137–140; Gross (1979), pp. 231–233; Clarke & Jacyna (1987), pp. 4–28; Hagner (1992), pp. 1–4, 31–33.

2 Clarke (1968), pp. 138–139; Rothschuh (1973), pp. 132–146.

3 See, for example, Albury (1974), pp. 98–99; Martensen (2004), pp. 191–194.

4 See Clarke (1968), pp. 123–141; Lesky (1970), pp. 297–314; Clarke & Jacyna (1987), pp. 279–280.

Gross claims that what contemporary brain anatomists and neurophysiologists understood as *nervous nutritional processes*—internal chemical transformations, the locus of sensibility, nutritive assimilation and selective absorption—should be interpreted as early attempts to explain the interrelation between nervous structure, development and regeneration.[5] These early modern doctrines survived into the twentieth century.

The case of 'nerve consumption theory' ('*Aufbrauchtheorie*'), developed by the well-known Frankfurt neuroanatomist Ludwig Edinger (1855–1918) at the end of the nineteenth century, may be taken as a starting point for my essay.[6] Edinger was a specialist of nerve regeneration, and his clinical work in neurology and laboratory research on animals served him well in relating physiological findings to morphological considerations. His importance for my argument arises because he utilised key physiological assumptions which had been central to the emerging science of nutrition.[7] Edinger's claim about the function of nerve nutrition, similarly, illuminates his view of the relationship between nerves, mind and metabolism:

> It is beyond any doubt that the function of the nervous system is based on nutritive processes, by means of which parts of the body are consumed, and these need to be regenerated. […] But what happens if the normal activity of the cell body is no longer equal to the metabolic replacement in the nerve, or if that activity is accelerated far beyond the [cell's] normal capacity for compensation?[8]

Edinger's description of the nutritive basis for nerve disintegration and nerve loss points to a central concern of earlier brain anatomists and physicians with neurological interests.[9] In their writings, 'animal nutrition' (*nutritio in animalibus*) united all physiological processes. The empiricism, natural history and natural theology of the 'long eighteenth century' rendered debates about the relationship between structure and function in the nerves and

5 Gross (1979), pp. 233–235.
6 Emisch (1991), pp. 91–93.
7 Holmes (1975), p. 135.
8 Edinger (1908), p. 1 (author's translation).
9 Cf. Stahnisch (2008a), p. 148.

brain particularly intense.[10] These nutritive exchanges, addressing the general exchange of matter between the body's physiological systems and the nerves, were seen as occurring on a small scale between different tissues, perpetually replacing the substance that was lost from an organ by vital action.[11] I shall offer an overview of the substantial topic of nerves, mind and nutrition, using the resurgent interest in nervous nutrition or *Nervennahrung* around 1900 as an historiographical lens. Furthermore, I shall trace the trope of 'nervous nutrition' back to the early modern period.[12]

2. Spirits, fibres and vital nerve functions in the early eighteenth century

There were major changes between the late eighteenth and early nineteenth centuries in key discourses about 'nerve nutrition', as historians have shown. These included increased use of direct observation and vivisectional experiments, emergent scientific philosophies such as the empirical school of the French *Idéologues*, and major social changes which allowed a new type of medical expert to appear, invested in the commercial application of research findings.[13] The aim of this paper is more limited. It will address the intriguing intertwining of different concepts and interpretations of nerve nutrition during the long eighteenth century.[14] The changes in the late eighteenth and early nineteenth centuries undoubtedly had important implications for scientific studies of the relationship between nerve anatomy, nutrition research, and neurological therapies in medical practice.[15] I interpret these interrelated transformations by appealing to pragmatic, epistemological and socioeconomic factors which helped to create and reshape a 'new science of nutrition'.[16] 'Nerve nutrition' was seen as determinative of the health and disease of both brain and

10 On Willis and Magendie as marking specific transitions in neurophysiology, cf. Smith (2007), pp. 15–28.

11 See also Orland's paper, this volume.

12 On 'brain food', see Gu et al. (2010), pp. E1–E8.

13 Lesch (1984), pp. 80–124; Spary (1996), pp. 178–179.

14 For an overview, see Rousseau (1973), pp. 137–157.

15 See, e.g., Porter (1993), pp. 225–285.

16 Holmes (1975), p. 135.

mind. But conceptual shifts at the end of the eighteenth century, resulting from new observational and experimental traditions in medical research, transformed many pre-existing relations between accounts of nerve structure, neurophysiological functions and the interactions between the brain and the peripheral nervous system.[17]

To begin with, I want to introduce some major proponents of seventeenth- and eighteenth-century anatomical and physiological nerve theories, before exploring the evidential basis for these theories. Lastly, I will relate the structure-function relationship of the nervous system to the basic processes of nutrition. Although historians have presented eighteenth-century nervous anatomy as an opposition primarily between two models of the nerves, the 'hollow tube' theory and the 'solid fibre' theory, in fact the picture was far more complex.[18] Adherents of the mechanical theory of nerve action followed the famous Cambridge mathematician, Isaac Newton (1643–1727), in modelling nervous function on the propulsion of physical particles. In this model of nervous force, by analogy with Newton's physical forces, an object at the peripheral end of the nerves could trigger small 'globules' to move along the nerve tract and transmit the external impression to the central nervous system.

The Newtonian mechanical model of nerve action applied the 'vibrating motion' of an ethereal medium to physiological processes.[19] This medium resided as a fine-grained substance in the fibres of the nerves, so that there was no need for them to be hollow. Physiologists following the Newtonian mechanical theory of nerve action now had two options for explaining how motion occurred in the hollows of the nerve tubes, processes which the physician George Cheyne (1671–1743) described as follows: 'Feeling is nothing but the Impulse, Motion or Action of Bodies, gently or violently impressing the Extremities or Sides of the Nerves, which […] convey Motion to the Sentient Principle in the Brain.'[20] René Descartes (1596–1650) in the seventeenth century, and many Newtonian neuroanatomists and physiologists writing after him, argued that physical particle

17 Gross (1979), pp. 231–233.
18 Clarke (1968).
19 Newton (1718), p. 328.
20 Cheyne (1733), Vol. 1, p. 71.

transmission occurred in the hollow of the 'nerve pipes'.[21] The nerves received the external particles through orifices in the sensory organs, and then transmitted their momentum to a corpuscular fluid existing in the interior cylinders of the nerve tracts. As Descartes had viewed it in his *Les passions de l'âme* (1649), the larger cylinders of the nerves were composed of smaller pipes that contained 'a kind of marrow composed of many very fine threads […]'.[22]

Fig. 1 Descartes's depiction of nerve transmission in a man perceiving the heat of an open fire via the sensory nerves of his toe (De l'homme, 1664) [Mackie Family Collection in the History of Neuroscience, University of Calgary]

When the particle momentum propagated through the nerves reached the brain, it was seen to act either on the cerebrospinal fluid or on the substance of the brain itself, which was

21 Descartes (1664), pp. 12–15.
22 Descartes, quoted in Clarke & O'Malley (1996), p. 159.

transformed, and eventually transmitted the impulsion to the soul. This model was upheld by what might be seen as a minor theoretical school, but was strongly advocated at the University of Leiden by the seventeenth century physician Franciscus de le Boë, known as Sylvius (1614–1672).

A second corpuscular tradition of nervous action was supported by a prominent group of mechanical philosophers, including Caspar Bauhin (1560–1624) and Thomas Bartholin (1616–1680) in France, Isband van Diemerbroeck (1609–1674) in the Netherlands and Thomas Willis (1621–1675) in England.[23] Willis localized the actions of the soul within circumscribed areas of the brain, cerebellum and cranial nerves. Following this research, a search commenced for evidence of the hollow structure of the nerves which enabled the flow of a quasi-magical fluid within the nervous system (*fluidum nervosum*).[24] This second group of mechanical neurophysiologists shared a faith in the existence of a hitherto unknown substance, able to traverse the minute, invisible 'porosities' (*porositates*) in the substance and sheaths of the nerves. The invisible substance (*substantia* or sometimes *spiritus animalis*) in the nerves would then transmit its impulse to nervous particles, transferring the momentum though corpuscular collisions within the nerve fibres. The dominant model involved chains of corpuscles within the nerve, which could transmit an impetus across long distances.[25]

This group had no particular need to postulate the existence of hollow nerves, since their theorizing relied on a corpuscular model of nerve fibres. Willis, for example, likened the nerve tubes in their porosity (*intra corpus ubique pervium, & poris innumeris appertum manere*) to the structure of an 'Indian cane' (a compact form of sugar cane), and described their inner arrangement as that of 'hair-like nervules'.[26] The Scottish physician David Kinneir (d. 1687?), who practised in Edinburgh and Bath, assumed that inelastic and solid 'fibres' completely filled the hollow nerves—rather like a mantle wrapped around a bundle of smaller pipes in the nerve's interior (*vasae in vas*)—and argued that the propagation of

23 Clarke (1968), p. 125.
24 Willis (1672), p. 91f.
25 Eadie (2003), p. 16f.
26 Willis (1670), p. 39f.

corpuscular motion from one nerve fibre to the next occurred by means of capillary attraction.[27]

Apart from the mechanical theorists, who either promoted the idea of completely hollow nerves or else favoured a porous model of the nerve tubes, another major group of brain anatomists at the end of the seventeenth and the beginning of the eighteenth century promoted the view that individual ‘hollow fibres’ were packed into the nerve tracts. Antonie Philips van Leeuwenhoek (1632–1723) in Delft, Albrecht von Haller (1708-1777) in Goettingen, and Herman Boerhaave (1668–1738) in Leiden held that a nervous fluid (*fluidus nervosus*) in the nerve tubes formed the mechanical substrate for the forward movement of individual corpuscles.

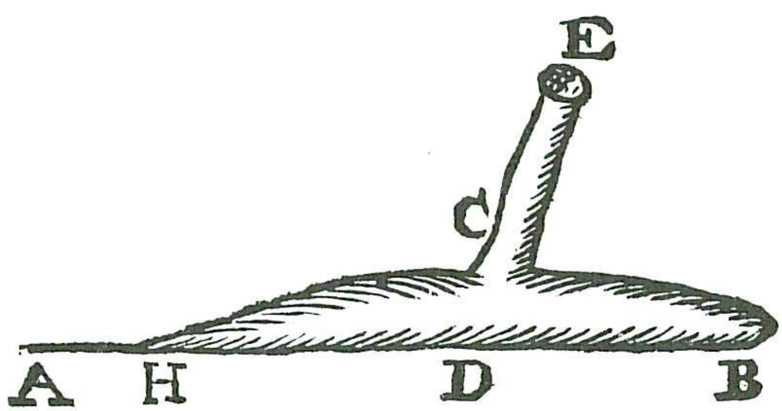

Fig. 2 Boerhaave’s depiction of a hollow nerve connecting with muscle (Leiden, 1734) [Library of the Max Planck Institute for the History of Science, Berlin]

A final group of neuromorphologists argued that the individual fibres in the nerve tracts were porous. These included Giovanni Alfonso Borelli (1608–1679) and Giovanni Battista Morgagni (1682–1771), who argued that the mechanical transportation of corpuscles within the nerves relayed sensory and motor impressions.[28] They regarded the nerve fibres as porous ‘canals filled with a spongy material like elder pith […], moistened with a

27 Kinnier (1739), p. 23f.
28 Finger (2004), pp. 102, 221.

spirituous juice originating in the brain', arguing that an unknown form of attraction was the cause of nervous action. For Borelli, there was thus no need to assume that the individual fibres of the nerves were hollow.[29] It is clear that in modelling nervous action, anatomists and physicians depended heavily on analogies and gross anatomical observation in the attempt to link mechanical explanations for corpuscular collisions within the nerve tubes, their fibres or the nervous fluids to their respective doctrines concerning the nerves.[30]

The models and analogies used to legitimize various mechanical concepts of nervous action made use of the latest research findings and technological developments. At the same time, they also drew upon earlier concepts which were still in circulation, and integrated these with their newer models. Naturalists like Borelli and Leeuwenhoek referred back to ancient theories, such as the writings of the Greek-Roman physiologist Galen (129–200/216), in advancing the view that quasi-gaseous or ethereal 'spirits' (as *spiritus nervorum*) were transmitted via pores or hollows in the nerve.[31] This view was also espoused by the German-Swiss physician Paracelsus (b. Philippus Aureolus Theophrastus Bombastus von Hohenheim; 1493–1541) and the Brussels naturalist Johan Baptista Van Helmont (1580–1644). Anatomical observations on the gross structure of the nerves gave new life to this view in the form of the doctrine of nervous spirits. The paradigmatic example here was the observation of 'hollowness' in human and animal optic nerves. However, this interpretation was often attributed to a conflation of the optic nerve with the central retinal vein and artery during the difficult dissecting process.

The alleged 'nerve juice' (*succus nervalis*) could be used to explain a number of neurophysiological functions, of which two are directly related to the topic of this paper.[32] Firstly, the nervous fluid could be interpreted as the structural substrate for the physiological nerve functions, supporting the physical motion of corpuscles by mediating mechanical 'collisions'. Secondly, the nervous fluid could also be understood as a nourishing substance, preserving the nervous system. Some nerve theorists, like the

29 Borelli (1681), p. 321.
30 Clarke (1968), pp. 128–129.
31 Eadie (2003), p. 14f.
32 Stahnisch (2008b), pp. 84–86.

Scottish physician John Douglas (1675–1742), assumed that the nervous fluid also played a pivotal role in muscle contraction, claiming that when small valves at the end of the peripheral nerves opened, the nervous liquid poured into the muscle fibres, causing them to swell. The same process happened in reverse after the contraction had occurred.[33]

This neurophysiological doctrine modelled neuromuscular action in quasi-hydraulic terms. It also relied upon analogies from other key seventeenth-century medical innovations, most notably the fascination with circulation. Famously, the London physician William Harvey (1578–1657) had discovered that blood circulated throughout the living body. Alfonso Borrelli, by injecting solutions of coloured wax into lymphatic vessels, had demonstrated the lymphatic system to be a network of hollow tubes throughout the body, through which lymph circulated.[34] In his later years, Henricus Regius (1598–1679) advocated viewing the nervous system, in similar dynamic terms, as a circulatory organ: 'The animal spirits, after being distributed from the brain to the whole body, are dissipated by insensible transpiration as well as by entering the veins, where they mingle with the blood and return with it to the heart. From there they proceed to the brain and again into the nerves.'[35] By further analogy, if the nerve tubes were hollow, muscle fibres too must have a lumen. Hence the nervous fluid was seen by Regius and his followers to flow into the muscle and provide it with the spring that enabled it to contract.[36]

3. Mechanistic, hydromechanical and vitalist explanations of nerve function

Corpuscular, mechanical and hydromechanical theories often coexisted during the eighteenth century, in particular in the work of eclectic neurophysiologists such as Herman Boerhaave, who was extremely important in reorienting the field of neurophysiology and the debate over nervous nutrition. Boerhaave successfully combined several contemporary doctrines in works such as the well-received *Anatomical Lectures on the Theory of Physic*

33 Douglas (1707), pp. 5–8.
34 Borelli (1681), p. 321.
35 Regius (1646), pp. 225–226, quoted in Clarke (1978), p. 295.
36 Clarke (1978), pp. 294–304.

(1743). This book integrated several theories with Boerhaave's own views about how the nervous fluid travelled from the cortex of the brain, down the spinal marrow, out into the spinal nerves and then through the peripheral nerve tubes to all parts of the body.[37] Boerhaave's mechanical conceptions were in line with contemporary views on the absorption of chemical and nutritive substances into the body, a process which physicians expressly referred to as 'nerve nutrition'. According to Boerhaave's theory, the only structures found everywhere in the body were the nerves, which demonstrated their prime importance for the body's physiology. He drew an analogy between this and the processes of the circulatory and lymphatic systems: 'In the same manner therefore as the arterial Blood and Lymph are perpetually distributed or moved into all the vascular Parts of the Body, so we also understand that the Juice separated by the Cortex of the Brain and Cerebellum is continuously propell'd from thence through the Nerves.'[38]

Boerhaave argued for a clear relationship between structure and function in the nervous system, for example in discussing the 'delicacy' of the nerves in women, children, and people with nervous or 'hypochondriac diseases'.[39] This view was subsequently refined by the Swiss-German physiologist Albrecht von Haller, recognized by eighteenth-century scholars as a major theorist of the fibre model of nervous action. Haller advanced the innovative claim that the 'sensibility' of the nerves to external stimuli was a structural property, and further suggested that muscle 'contractility' was the ability to move both voluntarily and involuntarily. From 1757 onwards, Haller also held that superfluous nervous fluid, having instigated movement within the body, could be absorbed from the peripheries of the organs and internal cavities, and transported back to the brain directly through the nerve tubes.[40]

Alongside physiological attempts to explain the nervous fluid as a mediator of corpuscular motion which transmitted external impulses within the peripheral nerves and the brain, a more specific discussion began in the eighteenth century concerning whether the nervous fluid could act as a source of nutrition. This trope became intertwined with

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37 Boerhaave (1743), pp. 310–313.
38 Boerhaave (1743), p. 313.
39 Porter (1993), p. 115.
40 Haller (1762), Vol. 1, p. 314.

ancient theories about ‘spirits’ or ‘vital forces’, seen as inherent properties of the nervous system.[41] A major protagonist of the nerve nutrition viewpoint, whose research spanned both morphological and physiological views of the nervous system, was the London anatomist Francis Glisson (1596–1677). He promoted the idea that the nerves were filled with an anatomically visible ‘nutritive juice’ (*succus nutrivus*) that was transported from the cerebral organ to the multitude of the nervous parts of the body.[42] He based this claim on his observation that a severed nerve or limb injury could lead to the withering of that body part, even though the structure and function of other nutritive systems such as the arteries and lymph vessels remained unaffected.

Glisson developed this model by suggesting that the *succus nutritius* travelled to the brain by way of the hollow nerves, a claim later endorsed by Haller, who attributed this circulatory role to what was then considered to be the sixth cranial nerve, the *Nervus vagus*, which had been found to have branches to most of the internal organs. Glisson also suggested that the nutritive fluid originated from the mesenteric glands in the intestines. Furthermore, he argued that the nerve sheaths themselves were constituted from fibres, and even though he did not observe tubes in their interior, either with the naked eye or using a primitive microscope, he nonetheless upheld the idea that both peripheral and central nerves were hollow. Glisson now combined this new view with the older models in which the nerves transported animal spirits. The *succus nutritius* transported animal spirits throughout the body, maintaining their vitality. Like air, the nervous or vital spirits were invisible. It was also the nervous system which nourished the nerves, supported their physiological function, and contributed also to the nourishment of other parts of the body.[43]

41 Eadie (2003), p. 14f.
42 Clarke (1968), p. 131f.
43 Glisson (1677), p. 162f.

Fig. 3 Glisson's depiction of a nerve-muscle preparation, showing the hollow nerve leading to the peripheral organ (London, 1654) [Library of the Max Planck Institute for the History of Science]

From the eighteenth to the early nineteenth centuries, dominant views of the general physiology of the nervous system and related concepts of the specific mechanism of nerve nutrition began to change as prominent French physiologists identified, redistributed and newly systematized the types of vital and nutritive action.[44] They attributed the vital actions (*actions vitales*) of the body to the specific organic fibre types. In addition, they circumscribed the roles played by nutritive forces in the various parts of the nervous system. Within this physiological programme of redistribution of the vital forces of sensibility and irritability in the living body, representatives of the Montpellier school—such as François Boissier de Sauvages (1706–1767) or Paul Joseph Barthez (1734–1806)—also ascribed a central role to the *liquide nerveux* that was postulated to exist in the inner tubes of the nerve tracts. Such views were primarily based upon clinical observation, which the Montpellier physicians generally valued over animal experimentation and anatomical dissection. They attributed the appearance of atrophy, muscle wasting or oedema in limbs following nervous diseases to changes in the composition of the nervous fluid itself, which altered its vital force (*force vitale*) by absorption or assimilation: 'All living parts are directed by a perpetually attentive force which constitutes the essence of the parts of matter [and] is the necessary result of its combination,' wrote Théophile Bordeu (1722–1776) in 1751.[45] Bordeu viewed the brain as

44 Gross (1979), pp. 233–238.
45 Bordeu (1751), p. 373.

a bodily ‘gland’ which secreted nervous fluid into the nerve tubes, altering the strength of the vital forces specific to the organs.

Bordeu and Sauvages both understood the physiological properties of ‘sensibility’ and ‘contractility’ as variably present throughout the body tissues. For this reason, they did not limit the vital forces to the nervous fibres, as Haller had done in discussing the sensibility of the peripheral nerves.[46] Rather, Bordeu located vital forces in all peripheral and central fibre systems. Nutritive processes, such as selective absorption, the assimilative force of the fibres or the phenomenon of glandular secretion, were claimed to reside only in the lymphatic system, gastrointestinal tract and adipose tissues.[47] If authors like Sauvages or Charles Louis Dumas (1765–1813) invoked vital forces, a characteristic feature of the explanations Montpellier physiologists offered for the properties peculiar to specific structures of the body, a considerable overlap between old and new philosophies yet persisted throughout the latter half of the eighteenth century. Mechanists in the seventeenth and early eighteenth centuries had investigated the identifiable structures of the nervous system in relation to the actions of physical impulses, and their role for nervous nutrition. The new French physiologists regarded the phenomenon of nerve nutrition in terms of its effects both upon the physical structure of the nerves and upon mental operations, sensation and locomotion.[48]

Montpellier vitalist neurophysiology offered several advantages over earlier traditions, such as its ability to explain the observed phenomena of life in animals and human beings. It also offered a new way to analyse physiological differences between organic structures. However, at the turn of the century there was disagreement concerning the best way of studying physiological phenomena.[49] Nineteenth-century physiologists, especially members of the Paris school of experimental physiology, strongly disagreed with the concepts of ‘sensible’ and ‘vital forces’ used by earlier Montpellier theorists and their Parisian supporter François-Xavier Bichat (1771–1802) to explain physiological function in the body in general and nerve nutrition in particular. Julien-Jean-César

46 Steinke (2005), p. 175–230.
47 Williams (1994), pp. 33–36.
48 Dumas (1803), Vol. 4, pp. 62–63.
49 Albury (1974), pp. 94–95.

Legallois (1770–1814), Georges Cuvier (1769–1832) and François Magendie (1783–1855) treated the nutritive properties of the nerves as differing only in quantity and degree, and as properties arising from the morphological structure or assemblages of organs. 'Cerebral or animal sensibility and voluntary contractility, as Bichat used to say, have only been included among the vital properties by a misuse of words. It is evident that they are functions or results of the action of a multitude of organs that share a common aim when working together,' argued Magendie in 1816.[50]

In the work of these Paris physiologists, the vital forces and nervous nutrition, assumed by the Montpellier physicians to be generally distributed throughout the body, came to be seen as localized within specific tissues or organs, such as the glands, intestines, autonomous and peripheral nervous system and brain. Here they were studied by physical and chemical experimentation, or through direct manipulation of the physiological phenomenon in question:[51]

> [The functions of the nerves] are the direct result of the actions of the nervous system and particularly of the brain. There is no need to find another explanation for them. One may observe or direct them, calm or extinguish them [in physiological experimentation], but one need not explain them any further.[52]

Magendie's *Précis* laid out the philosophical implications of the experimental approach to the physiological study of the nervous system, and of the nutritive processes taking place within it. When applied to the investigation of appetite, hunger and nutrition, the experimental method translated, for example, into a controlled manipulation of the eating habits of experimental animals. Though similar approaches had been systematically undertaken by Enlightenment investigators, the experimental series of Magendie and Legallois became increasingly extensive.[53] Vivisection was also used to conduct intensive studies of ingestion and digestion. Such experiments tested the capacity of different

50 Magendie (1816), Vol. 1, p. 17 (author's translation).
51 Stahnisch (2003), pp. 147–224.
52 Magendie (1816), Vol. 1, p. 185.
53 Olmsted (1944), pp. 62–73; Holmes (1974), pp. 141–143.

substances to sustain the physiological activity of the living body. Animal subjects were selectively starved, or fed with specific, monodietetic foodstuffs. The results of such investigations were constantly contested, particularly by clinicians, who argued that the experimental methods of ablation, cutting, ligation and so on used by experimental physiologists interrupted the natural functions of living beings, and produced experimental artefacts. But by 1820, experimental physiology had gained in credibility, partly by embracing and stabilizing concepts of appetite, hunger and nutrition as internal sensations resembling individual organic functions.[54] Magendie and other early-nineteenth-century experimentalists argued that these forms of 'internal sensibility' depended upon the integrity of the brain or the cerebrospinal fluid system which was claimed to nourish the nervous system.[55]

4. Nerve nutrition and models of mind

The physiological relationship between nerves and nutrition appropriated Enlightenment social views, new forms of empirical observation and the economic factors of the marketplace in the eighteenth century. All of these contributed to the radical transformation of understandings of food and nutrition.[56] One of the most profound and enduring changes in contemporary nerve theories resulted from the 'irritating experiments' of Haller and his pupils, which led to 'epistemological ruptures', in Bachelard's phrase.[57] The continuing attraction of mechanistic models is, however, evident in Haller's physiological investigations into nutrition. The Swiss physiologist incorporated a long-standing iatromechanical claim into his theory of fibres, in arguing that nerve particles from the sheaths and fibres were constantly being lost due to mechanical action.[58] Circumstantial

54 Williams (1994), pp. 132–133.
55 Cf. Legallois (1812), pp. 148–150.
56 Spary (1996), pp. 178–196.
57 Steinke (2008), pp. 206–224; Bachelard (2003), p. 337.
58 See also Holmes (1975), p. 135.

evidence that the nerves themselves played a nourishing role for bodily organs was provided by Haller's observation that injured or severed extremities became wasted.

> Since the nerves nourish the individual parts of the animal body, this must be assumed to be the highest function of the nervous fluid […]. The physicians of former times held the nervous fluid to be fully capable of undertaking this commerce, and they tried to demonstrate this view in many of their observations: If a nerve is injured, then the nourishment of the severed limb ceases as well (z); a limb which has lost its feeding nerve is stalled step by step and hence the paralyzed part becomes very weak. (a) Similar observations can also be made, when the spinal marrow (b) or even the brain are compressed (c).[59]

For Haller, physiological observation had shown that the nerves and the subtle transparent fluid in their delicate internal tubes (*ductus nervorum*) served to nourish the organs and preserve their structure. In support of this argument, he borrowed from the contemporary debate over the nature and bodily effects of electricity.[60] He also appropriated iatrochemical claims from the earlier part of the century which portrayed the nerves as recipients of the subtle spirituous part of foods.[61] The nerves themselves needed to be nourished in order to guarantee their functioning. As Haller had established, if a nerve was injured or severed, it would lose its former shape beyond the site of the injury; these morphological transformations of the nerves resulted from the loss of particles. The resulting holes allowed 'earthy' or 'gelatinous' ('*gelatinoes*') particles from the nutritive fluids to enter the internal nerve tubes.

Nutritional physiology played a similar role in leading neurological theories of brain function. In *Elements of the Branches of Natural Philosophy Connected with Medicine, viz. Chemistry, Optics, Acoustics, Hydrostatics, Electricity*, the London

59 Haller (1762), Vol. 4, p. 637 (author's translation).
60 Heilbron (1979), p. 30f. and pp. 211–215.
61 Iatrochemical theories of digestion, see, e.g., Clericuzio (in this special issue).

physician John Elliot (1747–1787)[62] discussed the physiological problem of nerve nutrition within a wider discussion of malnutrition. Elliot used the language of mechanics and chemistry to explain the impact of malnutrition on the nerves. Although Elliot did not explicitly discuss the German version of *Nervennahrung* in this natural philosophical work, he explained the starvation of the body and the exhaustion of the nerves in terms of a shortage of essential chemicals. If shortage was a situation of nutritive insufficiency, what counted as adequate nutrition for Elliot was a 'balance' between the materials consumed by the body.[63]

The mechanistic model of nutrition developed by Boerhaave and his student Haller was widely used in contemporary neurophysiology and neurochemistry. One of the first physicians to use the expression *Nervennahrung* was the Naumburg physician Elias Andreas Buechner (1701–1769), a member of the Imperial Leopoldina Academy of Natural Historians. The term appears in a physiological tract published in 1766 at the Cameralist University of Halle, *Von dem Nutzen der Nerven und des Cellengewebes zur Nahrung des Coerpers*.[64] Here Buechner discussed the role of the nerves in nutritive physiology, claiming that nervous function depended on the renewal of their structure ('*structura*') and action ('*actio*'): 'The author […] is of the opinion that a certain slimy fluid passes through the nerves and is responsible for nutrition. This fluid can be found in the tissues ['*Zellengewebe*'] and the smallest vessels of the nerves. Idleness weakens the nerves, while exercise strengthens them.'[65] Buechner was clearly using the expression 'nutrition' in much the same way as contemporary French physiologists and Haller, to refer to the replacement of lost matter within the body. He also cited the work of the Rouen surgeon Claude-Nicolas Le Cat (1700–1768), who had emphasised the importance of nutrition following surgery, particularly amputations. Buechner followed Le Cat's *Dissertation sur l'existence et la nature du fluide des nerfs, et principalement de son action pour le mouvement musculaire* of 1753 in linking nerve nutrition, accomplished by the nervous fluid, to muscular movement. He also agreed with Le Cat's claim that exercise

62 Mollon (1987), pp. 19–20.
63 Elliot (1786), pp. 65–69, 156–162.
64 On medicine at Halle, see Geyer-Kordesch (1990), pp. 67–87.
65 Buechner (1766), pp. 80–83; quoted pp. 81–82 (author's translation).

developed the muscles, while idleness deprived the organs of critical nourishment. This was a view which emerged after 1750, when physicians were once again suggesting exercise to their patients as a form of medical therapy. Doctors like Christoph Wilhelm Hufeland (1762–1836) in Weimar and Berlin now claimed that inactivity would increase corpulence.[66]

The appearance of Buechner's tractatus marks a decisive turn in human physiology, when the concepts of *muscle* and *fat* came to be distinguished in new ways. Fat was considered to contain an excess of nutrients and to give rise to unnatural textures and growth patterns, while muscle was seen as a balanced form of tissue.[67] Though Buechner did not specifically address Haller's views, only appearing in print as his own work was being published, he did quote heavily from Haller's teacher Boerhaave, who had earlier developed a theory about the primacy of nerve nutrition. Buechner agreed with Boerhaave and Haller that exercise had beneficial effects on the body, facilitating the flow of the nervous fluid through external compression. It could also be anatomically observed that the nerves of craftsmen were larger. Conversely, these physiologists invoked clinical cases in which palsies caused the wasting of limbs to support the claim that 'the nervous fluid was lacking as the strengthening agent of the nervous tissue […]'.[68] Buechner's view that good nutrition was necessary for proper nervous function may have been appropriated from earlier accounts relating the size of nerve structures to the powers of the nervous functions. He cited earlier writers, including Boerhaave and the anatomist Alexander Monro Primus (1697–1767), who identified a relationship between structure and function in the nerves, particularly emphasising the 'delicacy' of the nervous system of women, children, and 'hypochondriac' patients that was revealed by dissection.[69]

The Scottish physician Robert Whytt (1714–1766) famously espoused this view. Personal physician to 'mad' King George III (1738–1820), who suffered from a 'nervous' disease in later life, Whytt has been regarded as the 'father of modern neurology'.[70] In his

66 Clearly evident in Hufeland (1796), pp. 324–325.
67 Albala (2002), pp. 83–94.
68 Cf. Haller (1762), Vol. 4, p. 637; Buechner (1766), pp. 82–83.
69 Buechner (1766), p. 83.
70 Rocca (2007), pp. 86–87.

magnum opus, *Observations on the Nature, Causes, and Cure of those Disorders Which Have Been Commonly Called Nervous, Hypochondriac, or Hysteric* (1765), Whytt explained the structure-function relationship of the nerves:

> Women are more likely to be affected by ailments of the nerves than men […], because their nerves are much finer than those of men. On the contrary, elderly people who have lost most of the irritability of their nerves are less prone to such diseases. […] Their strings [the nerves] are no longer as firm and excitable as they are in a young body and particularly not as those in the female nervous system.[71]

Eclectic theorists like Whytt, Cheyne, or Haller combined different accounts of the relationship between structure and function in the nerves. Even so, their concepts remained ambiguous, probably because 'animal spirits' or 'nervous spirits' were not replaced by any other concept during the first half of the eighteenth century. Insufficient physiological knowledge then allowed functional roles to be attributed to nervous 'corpuscles', 'fluid', or 'nutrients', and for models based upon the 'commerce of the nerve particles'. By the end of the eighteenth century, there was considerable disagreement over which substrate could account for the influence transmitted via the nerves to the brain. During this transitional phase, there was extensive borrowing of earlier concepts, such as the doctrine of hollow nerves, the circulation of the nervous liquor and the exchange of matter between the nervous system and the organs. These models were not very compatible with one another from a theoretical point of view, but they were working tools which helped to develop new physiological and clinical explanations.[72]

Further neuroanatomical theories were also derived from practical circumstances. The German neuroanatomist Samuel Thomas von Soemmerring (1755–1830) was a core faculty member of the University of Mainz. Even so, he lacked access to a university laboratory, and his course on dissection was offered in wooden sheds outside the college.[73]

71 Whytt (1765), pp. 88–89 (author's translation).
72 See also Clarke (1968), pp. 138–139.
73 Dumont (2005), pp. 1–3.

In compensation, Soemmerring transformed a room next door to his kitchen at home into a dissection room, cramming his anatomical collection into it. Soemmering's house was also a regular meeting-place for guests such as the naturalist and explorer Georg Forster (1754–1794), Soemmerring's artist friend Wilhelm Heinse (1746–1803) of Aschaffenburg, and the Weimar polymath Johann Wolfgang von Goethe (1749–1832). Perhaps coincidentally, both Soemmerring and his pupil Jacob Fidelis Ackermann (1765–1815), who lived in the professor's house and 'shared his mensa table' for more than five years, became absorbed in research on the nourishment of the nervous system.

> In all likelihood, we can assume that the diameter of the primitive nerve fibres is greatly dependent on nutrition processes [*Ernaehrungsvorgaenge*]. Quite often, an increase in nutrition, the active movement of a limb, etc., generate bigger and stronger nerves. […] The elementary parts appear bigger than they are in very weak animals or in humans who are malnourished or atrophic or who have diseased body parts.[74]

Soemmerring's explanation of human mental actions, which appealed to mechanical and nutritional factors in the brain, had led to a vigorous controversy with the Koenigsberg philosopher Immanuel Kant (1727–1804). Soemmerring had asked Kant to write the foreword to his book *Das Organ der Seele* ('The Organ of the Soul') in 1796.[75] Kant, however, opposed Soemmerring's programme of reducing mental activities to physical phenomena, such as the 'nourishment of the nerves', and objected to the location of a specific 'organ of the soul' in the brain. In Kant's view, Soemmerring's book 'should never have been printed' because it would be 'absurd' to write that the soul could 'make itself apparent (*anschaulich machen*)' in bodily phenomena.[76]

Kant advanced two claims in his fervent critique, one epistemological and the other ontological. In epistemological terms, brain fluid was inappropriate as a vehicle for

74 Soemmerring (1800), pp. 40–41 (author's translation).

75 McLaughlin (1985), pp. 191–201.

76 Kant, letter 834, Koenigsberg in Prussia, August 5th, 1800 to Soemmering, in Dumont (2001), Vol. 20, pp. 402-403'.

transmitting the soul's impulses, because it was a fluid rather than a solid. This critique aligns well with views being expressed in French natural history and physics at this time. For Georges Cuvier (1769–1832) and others, to describe a bodily substance as disorganized would have meant that it lacked a solid structure, and so could not support physiological functions.[77] In his ontological claim, Kant went further, stating that the soul was clearly a 'transcendental' object, which could, *per principium*, not be localized in a physical substrate.

Soemmerring, aggrieved, replied that it was necessary to 'turn from the mechanical uniformity of water to its chemical composition, [where] there is more scope' for an adequate theory. Here he was making rhetorical use of the work of the French chemist Antoine-Laurent Lavoisier (1743–1794) to refute Kantian criticisms, even though to do so also led him away from a strictly mechanistic interpretation of nerve action.[78] This shift is further exemplified by the fact that after his dispute with Kant, Soemmerring's views on nervous function began to change, as he became preoccupied with corpuscular models of nervous transmission and nourishment, described as 'slow processes in the nerve tubes'. In later years, both as a physician in Frankfurt and then as a scientific member of the Bavarian Academy in Munich, Soemmerring emphasized 'electricity' as the major explanatory concept for nervous action. He was happy to find that the rapidity of electrical conduction explained the visible phenomena of nerve function better than models invoking 'wave transmission in humidity' ('*vereinigt wirklich die Feuchtigkeit der Hirnhoehlen alle gegen's Hirn zu erfolgende Nervenbewegungen*'), which suggested a comparatively slow process.[79]

Though Soemmerring was more interested in the nature of electrical nerve transmission, and tended to produce explanations by analogy, linking the physical phenomena to physiological observations, he did make use of contemporary work on 'animal electricity' by Luigi Galvani (1737–1798) in Italy.[80] In particular, Soemmerring related the accurate illustration of the sagittal batteries of his telegraphic apparatus to

77 Cuvier (1812), pp. 76–78.
78 Soemmerring (1811), pp. 5–6; Lavoisier (1789), Vol. 1, pp. xv–xvii.
79 Soemmerring (1796), p. 63–64.
80 Galvani (1791), p. 42.

Galvani's experiments with the serial alignment of fresh frog preparations on brass hooks in his laboratory.[81]

The preoccupation of neurologists with explanations involving particle motion and nervous nutrition continued through the late eighteenth and early nineteenth centuries, notwithstanding the fact that the French Revolution gave rise to a radically changed cultural context, increasingly dominated by bourgeois values of social conduct, and the introduction of gas lanterns in the 1780s and electric generators in the 1820s into urban living conditions. Accordingly, terms describing the temperament, excitability, and mechanism of nervous reactions to external stimuli, such as 'tenseness' (*Gespanntheit*) and 'mood' (*Stimmung*) '*Reaktionsspannung*', entered the standard terminology of neurologists.[82]

5. Reductive approaches to nerve metabolism at the turn of the nineteenth century

François Magendie headed a whole generation of 'experimental investigators', such as Legallois and Pierre Flourens (1794–1867), who created the new field of functional physiology. Knowledge about nutrition and dietetics had previously been widely related to the vital action ('*action vitale*') of the body, based on views about the interplay of the humours and the flow of organic fluids.[83] In early-nineteenth-century experimental physiology, however, there was an important epistemological shift away from the 'vital actions' of the body. Bringing the dietary requirements of humans or animals within a more quantitative research programme, experimental physiologists now sought to determine the normal quantities that humans and animals ate, while also identifying which were the most nourishing and healthy foods.[84] The transition to experimental physiology in the early nineteenth century merits scrutiny as a moment at which laboratory physiologists

81 He also reproduced Galvani's 1791 experiments: Soemmerring (1995), p. 282.
82 Roelcke (2001), pp. 183–185.
83 Coleman & Holmes (1988), p. 8.
84 Cf. Albury (1977), pp. 90–99, Pickstone (1981), pp. 115–142 and Lesch (1984).

reconceptualised the analogy between animals and humans in their research programmes on metabolism and nutrition.

Analytical experimentation not only offered a prestigious way of rethinking the actions of the animal economy (*économie animale*), it was also useful for framing France's technomorphic endeavours in what would later become a new biomedical age, with the advent of industrial society.[85] This meant that the emergence of a scientific understanding ('*le scientisme*') of the body's physiology and of its nutritive functions became analogically modelled on the new forms of production of the Industrial Revolution, such as the steam engine, the spinning jenny or the telegraph. French neurophysiologists' studies of the differentiation of sensory and motor functions of the spinal nerves, their elucidation of the functions of the facial nerves, and their investigations into the circulation of the cerebrospinal fluid, have already been the subject of extensive historical research.[86] Direct experimentation on nutritional physiology has attracted comparatively little attention. Researching problems of 'animal heat' and the interrelated processes of 'nutrition' over a long period, Magendie also sought to relate his research to wider public health applications. Thus, for example, he conducted experiments to settle the question of whether a gelatine-based diet was suitable to feed the Parisian poor, work which appeared under the aegis of the Paris Academy of Sciences between 1831 and 1841.[87] Magendie's personal involvement with this ongoing public debate gives further insight into the best historiographical vantage point for investigating the transition from the eighteenth to the nineteenth century. It also presents us with an opportunity to analyze some early relationships between science, commerce and society.[88]

The physiological problem of relating the structure of the nervous system to the functioning of the mind would merge with the social problem of the undernourishment of the deprived classes of contemporary French society. Magendie's well-known sensualist convictions were important in this connection, but were not the only factor behind his

85 Cf. Sarasin & Tanner (1998), pp. 12–43.
86 Cranefield (1972), pp. 46–51.
87 Stahnisch (2004).
88 Wilson (1998), pp. 81–84.

extensive experimentation.[89] In parallel with his nutrition experiments, he also sought to foster the claims of the emerging science of experimental physiology. I n so doing, he sought expert status for himself as a specialised laboratory investigator.[90] Though the philosophical empiricism current in the early nineteenth century prompted many improvements in physiological theory, instrumentation and experimental practice, the establishment of Magendie's laboratory system can only be understood in its entirety when the context of public experimental demonstrations is taken into account. To end with, I will scrutinize some of the entanglements between Magendie's experimental system of nutrition physiology and the French Academy of Sciences and the *École Polytéchnique*, so as to shed further light on the development of the concept of 'nerves, mind and metabolism' in the nineteenth century. I will explore the reasons why 'ordinary' foodstuffs such as meat, nuts or eggs developed into epistemic objects which were widely debated in nineteenth-century medicine.

The general theoretical outline of Magendie's physiological approach had been sketched out in *Quelques idées générales sur les phénomènes particuliers aux corps vivans* (1809), published at the end of Magendie's medical studies, shortly after his doctoral examination. His later *Précis élémentaire de physiologie* (1816-1817) summarised his physiological research, displaying the same philosophical commitments. He promoted an empiricist approach to physiology, using experimental observations upon animals as 'proof' that the vital actions of the body resulted from specific forms of physiological and anatomical organization of the body:

> No analogy, not even a probable one, has yet been found between the interplay of ordinary chemical affinities and the nutritive movement (metabolism); that is why that movement has always been, and still is, considered to be dependent upon a particular cause, which is undefined in nature, like planetary and molecular attraction, but manifest in its effects. [But …] what would be worth even more than

89 Stahnisch (2003), pp. 134–143.
90 Stahnisch (2004), pp. 120–122.

> all of this reasoning would be the performance of [animal] experiments with a view to find the general laws of this vital force.[91]

Experimental physiology here merits further investigation, because it distracted researchers' attention from the mechanical explanations that had been central in the eighteenth century, such as the modelling of corpuscular assimilation into the body upon eating.[92] Nutritive processes and, later, accounts of metabolism, became ever more specific, offering a prestigious way of redefining the animal economy in Magendie's programme, by showing that the two major phenomena essential to life were *nutrition* and *movement* mediated through nerve action, and by deriving these phenomena from the anatomical organization of animal and human bodies.

Though he studied the absorptive and nutritive functions individually, Magendie also created a bigger picture of the bodily functions as a whole, viewing ingestion, digestion and excretion as parts of an organismic process associated with the 'integrative functions' ('*fonctions de relation*') of the body.[93] Though Magendie's approach to the physiology of absorption, digestion and circulation in the body was broad, I shall confine my discussion to his research into nervous nutrition. This work was part of a much broader tableau established through different scientific interpretations of food and the changing social topographies of political decision-makers and healthcare administrators, which I like to summarize as the *metabolic compartments* of Paris.[94] Given the wider social concerns with 'nutrition', it is evident that the meaning of Magendie's experimental system was not confined to the *Collège de France*. Metaphorically speaking, the digestion and reuptake of information led a parallel life in the *Académie*, the *Bureaux de bienfaisance* and the medical establishment under the July Monarchy.[95]

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91 Magendie (1809), p. 145 (author's translation).

92 Holmes (1975), p. 138f.

93 Cf. Magendie (1817), Vol. 2, pp. 384–390.

94 The term 'nutrition' is used here in place of the modern term of 'metabolism', which only developed its current meaning of a bodily phenomenon relating to the conversion of food into energy or work in the 1840s, thanks to the work of Justus von Liebig (1803–1873). See Schiller (1974), p. 199.

95 Stahnisch (2004), pp. 103–134.

As an experimentalist, Magendie investigated foodstuffs in line with the philosophical commitments he had expressed in his 1809 *Quelques idées.* Conversely, however, his own empiricist convictions were not readily accepted by Parisian health officials, for whom they posed a major problem. At this time, the various 'metabolic compartments' of Paris were preoccupied with a bitter struggle over political and philosophical reconciliation within the French medical establishment.[96] Magendie must himself have been apprehensive, for he and his followers could not anticipate how French politicians would react towards his nutritional experiments, nor whether the whole 'commercial complex' of the period would change following the ongoing public health debates.[97] The strongest attack against Magendie's new physiology came from clinical physicians such as Vornelius Adriaan Bergsma (1798–1859), a corresponding member of the French Academy, who, while not questioning the use of animal experimentation in itself, argued that early-nineteenth-century laboratory investigators were barely able to master the setting for research. For example, Bergsma argued that Magendie's laboratory findings concerning nutrition could not be extended to real-life hospital conditions. Magendie and his pupil Claude Bernard (1813–1878), conversely, saw their opponents as presuming the existence of supplementary 'vital forces', which could not be reduced to the physical and chemical processes:

> Many physicians [who are] speculative physiologists, along with certain anatomists and naturalists, employ these various arguments to attack experimentation on living beings. They assume a vital force in opposition to physico-chemical forces, [which] dominates all the phenomena of life […] These ideas, which were current in other times, are now gradually disappearing; but it is essential to extirpate their very last spawn, because the so-called vitalist ideas […] are really an obstacle to the progress of experimental science.[98]

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96 Cf. Williams (1994), pp. 213–224.
97 On the general trend towards a scientific control of nutrition, see Orland (2006), pp. 17–46.
98 Bernard (1865), pp. 59–60. On this issue, see Stahnisch (2004), pp. 127–129.

This rebuttal of contemporary vitalist attacks on the epistemology of animal experimentation by Bernard is interesting for two reasons. Firstly, Bernard rejected the vitalist critique against vivisection, a practice central to the new experimental physiology, as artificial. To question the vitalists' assumptions about the existence of an unobservable entity, the 'vital force', was to place the burden of explanation upon them. Secondly, where the application of physiological experiments on nutrition was concerned, Bernard's comment attests to the distance travelled by experimental physiologists since the publication of *Quelques idées* in 1809. Back then, Magendie had suggested that there *were* such things as vital forces, whose nature was not completely understood, but which could in principle be addressed through systematic experimentation. Magendie's own views changed following the publication of the *Précis*, and Bernard argued against the existence of separate vital forces. Both nonetheless remained committed to the view that the experimental investigation of the physiology of living beings required a methodological approach different from that used for non-living bodies. Chemical analyses and physical observations were the route to understanding phenomena such as nutrition, while internal organisation and living conditions needed to be taken into account.[99]

Having mapped the important medical, epistemic and social problems developing with the advent of systematic animal experimentation at the beginning of the nineteenth century, I will now discuss the ambiguous role of laboratory animals in contemporary research on nerve nutrition.[100]

> When the trunk of the nerve is dissected within the cranial cavity, just behind its passage over the petrous portion of the temporal bone, the surface of the cornea becomes muddy twenty-four hours later, and a large web or cloud forms. After forty-eight to sixty hours […,] the conjunctiva and even the iris are inflamed. [...] Therefore, the nutrition of the eye is evidently influenced by the nervous system.[101]

99 For these notions see, for example, Magendie (1816), Vol. 1, p. 20; Bernard (1865), p. 95.
100 E.g. in his early 'Experiments on the Nutrition of the Eye', in his *Précis* (1816-17).
101 Magendie (1817), p. 475 (author's translation).

Magendie's view on the direct nutritive influence of the brain and nerves upon organ growth or decline resembles Haller's claims in the *Anfangsgruende der Phisiologie des menschlichen Koerpers* back in 1762. However, Haller was not explicitly mentioned when Magendie discussed nerve nutrition, even though the French physiologist was quite familiar with his work.[102] Though praising the Swiss-German physiologist, Magendie created an entirely new forum for innovative and advanced physiological research with the *Journal de physiologie expérimentale,* of which he was the founding and chief editor from 1821 onwards. He also pushed research into the nervous system and nutrition phenomena further than Haller had ever gone. Magendie's additional observations in various animal experiments, following ablative surgery of organ parts such as the stomach, peripheral nerves or various brain regions, seemed to corroborate his earlier feeding experiments on dogs, described in the *Précis*.[103]

Other French physiologists valued Magendie's experimental approach as a new practice for knowledge production, ensuring that appetite, hunger and other nutritive phenomena were an increasingly interesting subject, fostering experimental inquiries into possible substrates for nervous action which might account for the transmission of sensations, nerve impulses, and physiological forces. Essential to this was the surgical culture of experimentation taught at the *Écoles de Santé,* founded to replace the university medical faculties closed by the Jacobin government, where Guillaume Dupuytren (1777-1835), Magendie, Bernard and Jean–Léon de Poiseuille (1799–1868) trained.[104] Apart from the medical socialisation of this generation of physiological nutrition researchers, the particular manipulations involved in animal experimentation depended on a culture of laboratory investigation deriving from standard practice in human anatomy and surgery.[105] Magendie managed to make the interdependence of physiological state of nutrition and the nervous system evident with his demonstrations of the optic decay resulting from destroying the nerves supplying the eye, or of the seizures occurring after prolonged periods of mono-nutritive food supplies (e.g. sugar or gelatine diets). He was thus able to

102 Magendie (1816), quoted in Milligan (1824), p. 8.
103 See Stahnisch (2004), p. 111.
104 Olmsted (1944), pp. 15–16.
105 Temkin (1951), pp. 248–259.

provide experimental support for the claim made by many early modern brain anatomists and neurologists, from Whytt and Haller to Buechner, Soemmerring and Edinger, that nerve nutrition was a vital phenomenon, one in which the brain and spinal cord exerted a strong influence on the equilibration of the body's physiological metabolism. Eighteenth-century researchers had tried to demonstrate that the actions of the nerves and the mind were purely mechanical, while the new reductionist approaches of the experimental physiologists laid more emphasis on the nutritive and chemical substrate of the brain and nerves. This trend culminated in a socialist statement by the Dutch physiologist and chemist, Jacob Moleschott (1822–1893). Reflecting on the interrelation of malnutrition and behavioural problems in poor weavers' children in the neglected Prussian province of Silesia, Moleschott would remark: 'without phosphorus there is no thought!' ('*ohne Phosphor kein Gedanke!*').[106]

6. Conclusion

Today, many schoolchildren and university students in German-speaking countries are well aware of the social dimensions of 'nerve nutrition' (as *Nervennahrung*), when preparing for exams. In these contexts, *Nervennahrung*, or 'brain food' in recent English terminology, is now widely used in connection with the vitamin B complex, or the consumption of confectionery, for example. In the medical literature, however, historical references are limited to the introduction of sugar to the Western world, while other traditions of nerve nutrition are often completely ignored.[107] Likewise, vitamins, minerals and dietary fibre are nowadays presented as the 'new' nerve nutrients:

> The very strong influence of nutrition on human health is nowadays scientifically proven [...]. Many people have learnt their eating habits from their parents or even grandparents, who lived a lifestyle of hard physical labour. But most of today's

106 Moleschott (1861), p. 21.
107 Gu et al. (2010), pp. E1–E8.

> jobs demand high concentration under great time pressure. In the place of tea or coffee […], today's eaters need vitamins, minerals, micronutrients and fibres as long-term 'nerve nutrition'.[108]

Reflecting on this recent description of nerve nutrition from a handbook for medical practitioners, we may be reminded of Edinger's consumption model of nerve function, developed at the end of the nineteenth century, and with which I began this essay. In offering his patients practical advice about meat broth and physical exercise, Edinger worked on the assumption that a genetic and functional model of nerve metabolism must be represented in the relationship between structure and function and in the submicroscopic texture of the nervous system. In this paper, I have compared this view, manifested in neurological writings of Edinger's time, with various earlier traditions developed between 1660 and 1840. I have demonstrated that historians have often failed to attend to debates over macroanatomical changes in the nerves, explored by neuroanatomists in the 'long eighteenth century' as a source of difference between men and women, humans and animals, or different human races. During this period, a new account of the relationship between mind and nutrition arose in several interrelated contexts, including iatromechanism, iatrochemistry, vitalist and experimental physiological traditions. Here I have traced some of the important contexts in which the notion of *Nervennahrung* has appeared in the history of neuroscience, and described some of the social and economic contexts that gave rise to an important transformation of the field.

This change in theories of nerve structure and function was not the direct result of *a new* research outcome or *the decisive* move from clinical observation to brain anatomy, or of a vitalist critique of the experimental methodology in neurophysiology. Nor was it a well-defined succession of concepts and research approaches, as many historiographical accounts have claimed. Even the process of elimination of concepts which took place after the end of the early modern period has here been interpreted as a consequence of a major observational and empirical shift between the eighteenth century and the experimental

108 Sturm et al. (2006), pp. 118–119 (author's translation).

neurophysiology of the early nineteenth century. Nerve nutrition began to be discussed in physiological and anatomical writing from the late seventeenth century onwards by authors such as Willis and Whytt. Accounts of nerve nutrition were transformed in the debate on sensibility and irritability to which Boerhaave, Haller and Buechner contributed.[109] At the end of the eighteenth century, Soemmerring reinterpreted nerve nutrition within the context of a discussion of the physiological activity of the nervous fluid. Though introduced as distinct entities, neurophysiological and neuroanatomical concepts often coexisted, displaying considerable overlap. They did not represent a decisive breakthrough in the understanding of nerve nutrition. However, this situation also helped to preserve a variety of theoretical options until the early nineteenth century, at which point new avenues of enquiry made major changes in the physiology of nerve nutrition possible. Dumas, Magendie, Bernard and other French physiologists made this problem area the subject of their experimental investigations. Physiological theory and laboratory practice paved the way for altered forms of academic expertise which also acted as a tool for justifying existing forms of social and political commerce.

At all stages of the investigation, metaphors from everyday life were used to explain the actions and phenomena of the brain and mind, and these played significant roles in the clinical and research practice of neurology. In the middle of the eighteenth century ‘nerve spirits’, ‘nervous liquids’ and ‘nutritive juices’ were appropriated for new mechanical and hydraulic accounts of nervous function and nutrition. Later there was a shift from a mechanical model to a vitalist one, in which nervous action and life were no longer seen as reducible to mechanical actions alone, but rather as participating in the phenomenon of vitality or life, for which mechanical explanations could not fully account. For these reasons, nutritive issues and the textures of nervous tissues in the body continued to be interpreted in similar terms, despite these major transformations of explanatory models.

This paper has focused on nerve nutrition as an interface between physiology, medicine, philosophy and social discourse, analysing the chronological succession and

109 Vila (1998), p. 1.

parallel life of contemporary concepts and metaphors. Although major conceptual and methodological changes undoubtedly occurred during the long eighteenth century, there were also important developments in contemporary neuroscientific theories. Corpuscular, mechanical and hydromechanical theories of nervous nutrition coexisted, overlapping in certain areas. Neurophysiological interest in nerve nutrition can certainly be traced back to the rise of nervous disorders in the face of debates over civilisation, even if British and German approaches were not always consistent with the scientific and literary endeavours of the French Enlightenment.

Acknowledgements

This article is dedicated to my colleague and friend Margaret Jo (‘Maggie’) Osler (1942-2010), who passed away so unexpectedly. She did not live to see the paper on which she had so graciously commented appear in print.

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Nerves, mind and metabolism in the long eighteenth century

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