The Historiography of the Sciences of the Brain and Nervous System

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0. Introduction: Question of Scope

This chapter includes within its purview the historiography of scientific and medical work that long predates the formation of the discipline now known as neuroscience. The unification of biological, computational and medical sub-specialities that take as their subject matter the brain and nervous system of humans and other animals is very much a twentieth century phenomenon (see for example Smith (2000) and (Casper 2014a)). But like psychology, neuroscience as we know it today has a long past and, as I hope to show, there is a benefit to seeing how the history of the "neurosciences" is a strand in a larger story of the development of ideas and practices relating to mind and life within western European natural philosophy, at least from the seventeenth century onwards.

The topic that has received by far the most attention from historians is the issue of localisation of function within the brain and nervous system. Indeed, many histories of neuroscience define their project just as the recounting of discoveries of the relationship between localised neural structures and particular functions and disfunctions, from ancient times to the present. In the next section I offer a brief and by no means exhaustive review of scholarship on localisation. As I see it, an important task for historians of the neurosciences is now to forge connections between this body of work and the history of a range of other topics, including the concept of reflex, and the more general characterisation of mechanistic approaches to the nervous system (Section 2), as well as the synthesis of neurobiology and computational theory that occurred in the mid-twentieth century (Section 3). In Section 4, I discuss work that makes evident the links with the historiography of other domains of biology such as evolution and the cell theory. I close in Section 5 with a tour of studies that link the trajectory of brain science with trends in wider society, including technological innovations, scientific racism, and materialist conceptions of the self.

1. The Varieties of Localisation

The conception of localisation of function has, historically, taken many forms. While neuroscientists today often now associate localisation with the thesis that cognitive functions are supported by small, isolatable regions of the cerebral cortex in humans and other mammals, historically important treatments of localisation concerned instead the contrasting functional roles of peripheral nerves, or the gross functional difference between neocortex and the mid-brain and brainstem structures. This illustrates how theories of localisation were themselves dependent on the available conceptions of neuroanatomy: to the extent that localisation presumes there are fixed structure-function relationships, the way that the brain and nervous system are parcelled into structures will shape the possibilities for association with functions. For example, the physician Thomas Willis (1621-1675) is credited with many early discoveries in neuroanatomy, and did not hesitate to assign different functions to the macroscopically observable structures of the brain. As Arikha (2006: 159) relates, Willis assigned, "the common sense to the corpus striatum, the imagination to the corpus callosum and memory to the grey matter". One should not ignore the way, also, that localisation theories tend to borrow the taxonomy of functions from available theories of mental operations. Willis' tripartite division into faculties for imagination, memory and common sense, is reminiscent of the medieval scheme of faculties. Below we will see how combinations of neuroanatomical and psychological[1] schemata generate various kinds of localisation theories.

Another important dimension in the characterisation of localisation theories is in terms of what the localisation thesis is put forward in antithesis to; for instance, against the conception of a brain consisting of functional networks rather than discrete "organs", or in contrast to the notion that brain tissue is quite functionally homogeneous. This last option is sometimes called "equipotentiality", but this is different from the definition given by Karl Lashley, the neurophysiologist and psychologist with whom the term is most associated:

> The term 'equipotentiality' I have used to designate the apparent capacity of any intact part of a functional area to carry out, with or without reduction in efficiency, the functions which are lost by destruction of the whole. This capacity varies from one area to another and with the character of the functions involved. It probably holds only for the association areas and for functions more complex than simple sensitivity or motor co-ordination. (Lashley, (1929: 25)

The idea here is that brain tissue is not forever fixed in its operations, but can compensate for the damage or loss of parts within a functional area, and it is interesting that this possibility of plasticity and compensation is in fact granted by the localisers of the 19th century, such as

[1] Using the term anachronistically to describe any study of mental function.

David Ferrier and Eduard Hitzig.[2] Another point of reference in the background of discussions of localisation is the changing conception of the relationship between the two hemispheres of the cerebrum, especially during the 19th century: whether asymmetrical or perfectly similar, as required by some metaphysical theories of the unity of the mind (Harrington 1987).

1.1 Cortical Localisation

The controversial work of the phrenologists, in particular Franz Gall (1758-1828) and Johann Spurzheim (1776-1832), has received much scrutiny from historians. Indeed, phrenology tends to dominate the conception of what localisation is essentially about, such that critics of contemporary research on cortical localisation and brain imaging cast the project as a "new phrenology" (Uttal 2001). Historian Laurent Clauzade (2018) relates the history of criticism of phrenology as a "false science", and the polemical use of the history of the discipline is facilitated by phrenology's having been taken up as a bogeyman amongst philosophers of science engaged in arguments about the demarcation of science from pseudo-science (e.g. Thornton 2018). The movement has received more nuanced treatments from historians of science concerned to understand the relationship between the phrenologists' detailed anatomical pursuits and their aims as social reformers (Shapin 1979), or personal ambitions (Wyhe 2004), while other works have sought to assess the role of phrenology as a precursor to contemporary neuroscientific localisation theories (Young 1970: chapter 1; Métraux 2018).[3] Métraux's work is also notable for its "close looking" at the visual productions of the phrenologists: drawings of skulls as well as the iconic phrenological heads.

A number of studies pursue the theme of localisation from the time of the phrenologists into the twentieth century, observing the various pendulum swings back and forth between conceptions of brain areas as more or less specialised, and noting the different ideas of what exactly is localised, be it the psychological faculties of Gall, or the simple sensations and muscle representations that were posited later in the nineteenth century (Tizard 1959; Hecaen and Lanteri-Laura 1977). One much-referenced work, which covers the period from Gall to Ferrier's publications of the 1870's, is *Mind, Brain and Adaptation in the Nineteenth Century* by Young (1970). An important feature of this work, along with Smith (1973) and Danziger

[2] I thank JP Gamboa for this observation.

[3] See Section 5.1 on the relationship between phrenology, scientific racism, and the justification of colonialism in the 19th century.

(1982), is the attention paid to the role of associationist psychology in Britain in shaping the course of neurophysiology and neurology in the anglophone world.

Many of the figures associated with the genesis and unfolding of the research on cortical localisation that occurred during the 1860’s-1880’s have been the target of biographies which offer narratives of their well-known observations and discoveries, such as Critchley and Critchley (1998) on John Hughlings Jackson, alongside Stanley Finger (2000) on Paul Broca, David Ferrier and Eduard Hitzig. A different approach has been to focus on a particular phenomenon or pathology and compare how views on its neural substrate evolved within different contexts and research traditions, such as Greenblatt (1970) and Lorch (2008) on the “encounter” between John Hughlings Jackson and Paul Broca, regarding the interpretation of aphasia.

It is also worth mentioning the existence of writings by the subsequent generation of neurologists and neurophysiologists in which favoured interpretations of the localisation theory are expounded and defended. Two examples are Ottfried Foerster (1936) and Sir Francis Walshe (1961) on the question of whether or not Hughlings Jackson was a “strict localizer.” When analysing the late 19th and early 20th century, there is an important question about how best to characterise and assess the motivations of the *opponents* of localisation, who can no longer be characterised as anti-materialists and defenders of the status quo, as is the norm in accounts of the debates over phrenology. Rather, disagreements seemed to have occurred over the overall plan of functional organisation of the brain, and how it supports cognitive capacities. The most satisfying work on the localisation debate in this era stands out for its treatment of these points of difference, and the connections drawn across relevant views in psychology and biology. For instance, Anne Harrington (1996) analyses the “holistic” theories of the nervous system function put forward by neurologists Constantin von Monakow and Kurt Goldstein in the context of a broader opposition both to mechanistic physiology and associationist psychology, which had significant political and social connotations in Weimar Germany. In another rich study Katja Guenther (2015) contrasts the localizationist *Zentrenlehre* of Carl Wernicke and Theodor Meynert in the 1860’s and 70’s with the “connective” approach championed subsequently by Foerster and which, Guenther argues, is an important part of the background to Freud’s psychoanalysis.

1.2. Specialisation of Function in the Nerves

In contrast to the substantial literature on cortical localisation, the early findings on functional specialisation of the nerves have received less attention from historians. That said, the controversy during the 1820's between Sir Charles Bell and François Magendie over the priority of the discovery of the roots of sensory and motor nerves was examined in detail by Clarke and Jacyna (1987). In addition, a recent monograph on Bell by Carin Berkowitz (2015) adds important contextual information regarding institutionalisation of medical training in early nineteenth century London, and the contrasting disciplinary cultures of anatomy (Bell) and physiology (Magendie).

Edwin Boring (1950: chapter 5) credits Johannes Müller not as a discoverer of the functions of the nerves, but as a theoretical systematiser of the recent findings, as he presented them in the "laws of specific nerve energies" in the 1838 edition of his *Handbuch der Physiologie des Menschen*. The reception and impact of the "laws", and Müller's influence on the course of the neurosciences more widely, is a fascinating issue that still calls for further study. Isaac (in press) argues that the laws of specific nerve energies were profoundly influential in the development of philosophical structuralism, via Helmholtz and later neo-Kantians (see also Patton 2018; Hatfield 1990). In *Müller's Lab*, Otis (2007) analyzes Müller's institutional role for the biological sciences in mid-nineteenth century Berlin. The book includes chapters on his mentees, Emil du Bois-Reymond and Hermann von Helmholtz, whose contributions to the physiology of the nervous system have in turn been the subject of numerous studies (see Section 5.2).

2. The History of the Reflex

The discovery of the separation of function of motor and sensory nerves is connected with the emergence of the modern conception of the reflex arc – a circuit involving a sensory nerve that is activated in response to an external stimulus and which elicits a predictable, involuntary motor response via activation of a corresponding motor nerve. Credit for the experimental results leading to this conception is given primarily to Marshall Hall (1833), with Johannes Müller taking a strong secondary role (Clarke and Jacyna 1987: chapter 4). That said, the concept of the reflex is usually said to long predate the 19th century anatomical and physiological discoveries, with the physiology of René Descartes coming to the foreground as the site of a contested legacy. The case of the reflex is particularly interesting from the historiographical point of view because it is an instance of a historical narrative first constructed by scientific professionals later coming under the critical scrutiny of a historian of science, Georges Canguilhem. I will first discuss Canguilhem's response to the standard narrative that traces the reflex concept back to Descartes, before then discussing recent scholarship on the Victorian debate over free will, which took place in the shadow of the ascendant reflex theory of the brain.

2.1 Canguilhem on the Reflex Concept

Canguilhem's *La Formation du Concept de Réflexe aux XVIIe et XVIIIe Siècles* (1955/2015) was one of the first monographs on the history of the neurosciences written by a historian and philosopher rather than a scientist. It has not yet received a complete translation into English,[4] though it has attracted interest for its historiographical approach – the tracing of the formation of a particular concept – which is discussed at length by Schmidgen (2014b). Canguilhem's work is a response to the book *Reflex Action* by Franklin Fearing (1930), an American professor of psychology, whose work is also discussed by Roger Smith (1992: 20), noting the historiographical legacy of Conrad Eckhard (1881). Canguilhem argues that the familiar narrative presented by Fearing systematically overlooks the contributions of research in the "vitalist" tradition concerning the reflex neuro-muscular system, and overstates the relevance of "mechanists" such as Descartes. To put it crudely, Canguilhem's accusation is that a Whiggish impulse of later mechanists, such as Emil du Bois-Reymond, to find their own philosophical presumptions reflected in the history of their discipline is what led to this distortion. See in particular Canguilhem (1955/2015: 139-42), where the argument is based largely on the text of du Bois-Reymond's (1887) memorial lecture for Johannes Müller. One of Canguilhem's positive claims is that the seventeenth century figure who can be credited with first formulating the reflex concept is Thomas Willis, and moreover, that the "iatrochemistry" that provided his theoretical outlook is continuous with the tradition exemplified in the 18th century by J. A. Haller and Georg Procháska, who also made important experimental and conceptual contributions, while departing from the Cartesian tenet that the inner workings of organisms are fundamentally no different from those of inorganic machines.

Importantly, Canguilhem's claims regarding the reflex are bound up with the historiographical view, expressed in his well-known essay, "Aspects of Vitalism" (Canguilhem 1965/2008a), that the history of the biological sciences is characterised by a sustained oscillation between what he names mechanist and vitalist tendencies. This stands in contrast with a narrative, popularised in the late nineteenth century by such figures as Thomas Henry Huxley in his public lectures (e.g. Huxley 1875), and still put forward by some philosophers of science (e.g. Craver and Tabery 2017), that the biological sciences since the seventeenth

[4] Canguilhem (1994) is an excerpt.

century have been on a linear trajectory in which the mechanistic conception of life is ever more dominant. Thus, the specific claims about the development of the reflex concept stand or fall with these broad commitments regarding the long arc of the history of biology. One might be wary of Canghuilhem's advocacy of vitalism. However, it should be noted that he does not define "vitalism" as an ontological commitment to vital forces but as a kind of "positivism" in which biological phenomena, such as the "irritability" of nervous tissue, are taken at face value, not as demanding metaphysical exposition or reductive explanation in physical or chemical terms (Canguilhem 1955/2015: 113).

That said, assessment of the thesis about the broad shape of the history of biology is beyond the scope of this chapter. I will mention, in passing, that one contemporary historian of science, Jessica Riskin (2016), does depict a comparable oscillatory history, which swings, in her framework, between "active" and "passive" versions of mechanism – the claim that the mechanisms of living systems do or do not have an intrinsic agency. In addition, a number of historians have taken the generational shift from the era of Johannes Müller's *Naturphilosophie*-influenced research on neurophysiology to that of his students Hermann von Helmholtz and du Bois-Reymond, who stood self-consciously for an approach to physiology which aimed at assimilation with the physical sciences, to be of great significance for the history of the discipline (Otis 2007; Harrington 1996: chapter 1). Another historiographical perspective considers whether categories such as mechanist and vitalist should be reconceived as stances regarding the reducibility or autonomy of biology, as argued by Ernst Cassirer (who was Kurt Goldstein's cousin) in his survey of the then recent history of biology (1950: part 2, chapter 11), or if such categories are too broad to be anything but misleading when applied to the detailed texture of particular schools and laboratories.

The role of Charles Scott Sherrington in the story of the reflex concept merits much scrutiny. For instance, Casper (2014a) situates the notion of "integration" within the story of the formation of neuroscience as an interdisciplinary field during the twentieth century, while Fearing (1933) presents Sherrington's *Integrative Action of the Nervous System* (first edition published in 1906) as the culmination point of experimental research on the reflex, elaborated into a comprehensive theory of the operation of the nervous system. It is worth noting that Sherrington's use of the reflex, as both an experimental and theoretical device, is one of the main targets of Kurt Goldstein (1938) in his criticisms of the "atomistic" approach to the organism. As Wolfe (2015) points out, Goldstein was a key influence on Canguilhem, with Goldstein's "holism" being closer to Canguilhem's "vitalism" than any of the oft-declaimed vital-force theories. Yet Goldstein's Sherrington is something of a caricature, since Sherrington himself is ready to admit that the notion of an isolatable reflex is a "purely abstract conception" and a "convenient, if not a probable, fiction" (Sherrington 1906: 8). A more detailed study might reveal Goldstein and Sherrington to be closer to one another than had first seemed.

2.2 The Reflex Theory of the Brain and the Debate over Free Will

Until the mid-twentieth century, the spinal cord and peripheral sensory and motor nerves were vastly more accessible as experimental preparations than the brain itself. It should not be surprising, then, that the relatively more developed theory of peripheral function – encapsulated in the notion of the reflex arc – should have been taken as a key to the understanding of central function. This is the move made by the physician Thomas Laycock in his 1845 presentation of the reflex theory of the brain, which was endorsed by Hughlings Jackson in his 1875 pamphlet, "On the Anatomical and Physiological Localisation of Movements in the Brain" (Hughlings Jackson 1931/1985). Laycock (1845:298) proposed as follows:

> the ganglia within the cranium being a continuation of the spinal cord, must necessarily be regulated as to their reaction on external agencies by laws identical with those governing the functions of the spinal ganglia and their analogues in lower animals.

The spinally-mediated reflexes occur with a fatal inevitability, like the cause and effect chains in a simple machine. For this reason, the hypothesis that all the operations of the brain are essentially reflexes was taken by many to imply that this organ also operates in a deterministic fashion, ruling out free will. The Victorian debate over free will is treated in all its dimensions (including the philosophical and theological ones) in *Free Will*, an impressive study by Roger Smith (2016). Of particular relevance here is the 1870's controversy over the theory of "conscious automata". In typically polemical style, Thomas Henry Huxley (1875) presents a case that experienced mental states are never causally efficacious, and that the nervous system is an elaborate mechanism of nested reflexes. He appeals both to contemporary observations of the almost-normal behaviour of decerebrated frogs, and of a brain-damaged soldier undergoing episodes of unconscious "automatism". As mentioned above, Huxley presents the reflex theory as the culmination of an illustrious history of mechanistic investigations into the nervous system, beginning with Descartes.

Huxley's account was almost immediately contested by the physiologist William Benjamin Carpenter, author of widely read textbooks, who reported that,

> nothing in the results of more recent researches [was found] to shake my early formed conviction of the existence of a fundamental distinction, not only between the rational actions of sentient beings guided by experience, and the automatic movements of creatures whose whole life is obviously but the working of a mechanism. (Carpenter 1875: 397)

William James published arguments against the automata theory both in (1879) and (1890: chapter 5). In a recent study of the place of religion in Victorian science, Matthew Stanley (2015: chapter 6) contrasts Huxley's attack on free will with the physicist James Clerk Maxwell's defence, and explains the dispute as part of a wider contest in Britain between the waning "theological science" and the ascendant "naturalistic science", which was itself a struggle for the control of institutions of scientific education between an establishment in thrall to the Anglican church and a movement of self-made men, often religious non-conformists, such as Huxley. One may compare this with the case put forward by Chirimuuta (2017) that a shared commitment by physiologists in the 1870's to the doctrine of the causal closure of the physical (a metaphysical presupposition of the automata theory) was motivated, at least in part, by the practical expediency of defining the subject matter of neurology and neuro-physiology in terms of causal mechanisms subject to experimental interventions.

3. The Origins of Computational Neuroscience

Fearing (1930: vii) ranked the "reflex arc concept" as comparable in stature with the "fundamental explanatory principles of physics and chemistry." Although the book concludes with the thought that the approach does not "yield a complete account of experience and behaviour" (1930:315), there is no intimation that the classical reflex theory of the nervous system is about to be replaced, root and branch, by a new alternative. Indeed, the displacement of the reflex theory turned out to be far more complete than the replacement of classical mechanics by modern physics. Classical mechanics never left the physics curriculum or disappeared from general use in applied science, whereas the reflex theory of the brain no longer appears in contemporary textbooks. The dramatic fall of the reflex theory is a matter that still awaits detailed historical treatment. One important question is how its decline may or may not relate to the rise of computationalism, in the years following the second world war, as a theoretical framework for much neuroscientific research. Shepherd (2010) discusses the rise of computational theory in neuroscience in the 1950's as part of a larger picture of the coalescence of numerous other specialities to form the multidisciplinary field of neuroscience, as we know it today. It should also be appreciated that there was, in parallel, a surge of informational thinking within molecular biology at this time (Kay 2000).

Cybernetics – the interdisciplinary science and engineering of intelligent or self-governing systems that emerged during the post-war years – has experienced a wave of historical interest, with recent monographs by Ronald Kline (2015) and Andrew Pickering (2010), and numerous other relevant studies. Since the home discipline of many of the protagonists within cybernetics was neurophysiology or psychiatry, much of this scholarly output is highly relevant to the history of the neurosciences. For example Tara Abraham (2016) has published the first biography of the medically trained neurophysiologist, Warren McCulloch. The most recent edition of McCulloch's collection, *Embodiments of Mind,* includes reflections by neuroscientists Jerome Lettvin and Michael Arbib on the significance of McCulloch's work, which offer plenty of interesting though often anecdotal material about the formation of the computational theory of the brain (McCulloch 2016).

Historical research has tended to focus either on the British or American networks of cybernetic research, and the fora for interdisciplinary dialogue that occurred in those countries – e.g. the Macy conferences and MIT labs in the US, and the Ratio Club in the UK. The Ratio Club appears to have been an important conduit for the transmission of information theory and computationalism into British neuroscience, not least because its membership included Alan Turing, Donald MacKay and Horace Barlow (Barlow and Husbands 2008; Husbands and Holland 2008). Interesting questions remain for comparative research: for example, were the principles and methods of the two "schools" largely shared, and can any divergences be accounted for in terms of the different nature of cold war politics in these two contexts? Moreover, it is important to consider activity beyond the Anglophone world, especially the Soviet Union. For example, Gerovitch (2002: chapter 5) argues that through adapting the language of cybernetics to his own purposes, the physiologist Nikolai Bernshtein was able to evade some of the charges of "vitalism" and "idealism" that had been directed to his non-Pavlovian (and hence politically transgressive) research on motor control.

The term "cybernetics" is usually reserved for research produced during the 1940's-60's. However, much of the "artificial intelligence" work of the 1970's and 80's is continuous with cybernetics, as related in the very comprehensive history of AI by Margaret Boden (2006). Of particular relevance to our study is the development of *neural network* or *connectionist* modelling, which began with Frank Rosenblatt's (1958) "perceptron" model. It is commonly recognised that this brain-inspired style of AI has co-evolved with neuroscience. On this topic, the book *Talking Nets* (Anderson and Rosenfeld 1998) is a valuable resource – a collection of interviews with seventeen of the early developers of connectionist models, including neuroscientists Walter Freeman, Stephen Grossberg, and Jerome Lettvin,

4. Some Points of Contact with the History of Related Disciplines

This section examines three topics in which the themes elsewhere in the history of biology intersect with research on the history of the neurosciences – evolutionary theory, cell theory and the history of medicine. This does not, of course, exhaust the possible points of connection but is intended to highlight some areas in which important work has already been done, and to give an indication of other avenues for future research.

4.1 Evolutionary Theory and the Brain

The story of the sciences of brain and mind in the latter half of the 19th century cannot be understood without consideration of the contemporary rise of evolutionary biology. The incorporation of Darwin’s theory into accounts of mind and behaviour in the anglophone world is given a detailed treatment by Robert Richards (1987). Alongside Ernst Haeckel, Emil du Bois-Reymond was a major populariser of Darwinism in the German-speaking world, as discussed by Finkelstein (2013: chapter 11). The incorporation (and alteration) of Darwin’s theory by psychophysicist and philosopher of nature, Gustav Fechner, is discussed by Heidelberger (2004: chapter 7), in an account which illustrates the philosophical richness and diversity of theorising about the mind, nervous system, and its place in nature, that occurred at this time.

Herbert Spencer’s theory of evolution – which, in contrast to Darwin’s, posited an inherent progressive tendency in which life forms evolved from homogeneous to more heterogeneous states, and allowed for inheritance of acquired characteristics – had a large impact on the history of neuroscience. The significance of Spencer who, it should be noted, had an interest in phrenology at an early stage in his career, is the topic of Young (1970: chapters 5 & 6). As argued by Feuerwerker, Couillard, and Gauthier (1985), Spencer was a major influence on Hughlings Jackson, and through Jackson, on Charles Sherrington. Evidence for the significance of Spencer is abundant in Jackson’s “Croonian Lectures on the Evolution and Dissolution of the Nervous System” of 1884 (Hughlings Jackson 1932/1985). In this work Jackson depicts the entire central nervous system in terms of an evolutionary hierarchy of lower to higher structures (the cerebral cortex in man being the most “evolved” structure). The notion of “dissolution” – the reverse process of evolution – is employed to explain a variety of neuropathological conditions. Arguably, this idea became disseminated within 20th century neurology as the notion of "degeneration" of neural structures and pathways.

Jackson was not the only one to conceive of neuropathology as a manifestation of dissolution. In the work of John Langdon Down, this had an overtly racial aspect with different kinds of cognitive disability being accounted for as a degeneration to the condition of a "lower" race – the most well-known being the characterisation of the condition now known as Down's syndrome as "the Mongolian type of idiocy" (Down 1866). Down is a particularly striking example, but the racial connotations of the evolutionary picture of the nervous system are at least there implicitly in the writings of other authors of this period. (And see Section 5.1.)

4.2 The Cell Theory and the Neuron Doctrine

Another landmark event in 19th century biology was the development of the cell theory, following the microscopic observations of Henle and Schwann in the 1830's (Otis 2007: chapter 2). Subsequent to the formulation of the cell theory, the "neuron doctrine" is the thesis that the fundamental developmental, anatomical and physiological units of the nervous system are the single neuron. Shepherd (1991) is a comprehensive study of the development of the neuron doctrine from observations of Jan Purkinje in 1837 to the forging of a consensus in favour of Ramón y Cajal's version of the neuron doctrine around 1906. One useful feature of this monograph is that it includes, within the main text, long excerpts of primary sources in translation.

The dispute between the anatomist Ramón y Cajal and Camilio Golgi (inventor of the staining method employed to great acclaim by Cajal), concerning Golgi's advocacy of the recticular theory – which posits that the nervous system comprises one continuous network – is of particular interest because it draws attention to the way that a new microscopy technique could generate images subject to multiple interpretations bringing with them incompatible theoretical outlooks. The 1906 Nobel speeches of Golgi and Cajal are interesting documents, not least for their contrasting rhetorical manoeuvres (Golgi 1967; Cajal 1967).

Because the work of Cajal is so visually rich – he executed very attractive, detailed pen and ink drawings of different kinds of neurons, in various species and at different stages of development – and is valued as an aesthetic as well as a scientific achievement, Cajal has been the focus of scholarship on the topic of neuroscience and art. DeFelipe (2010) is one such work, and worth examining also is the catalogue of the 2018 exhibition, "The Beautiful Brain: The Drawings of Santiago Ramón y Cajal" at the Grey Gallery, New York University (Newman, Araque, and Dubinsky 2018). Beyond the focus on Cajal, there are issues to be explored on the topic of neuroanatomy and scientific representation more generally, and understanding how social context, and the communicative ambitions of scientists, affects the choice of representational forms. Some notable works in this area are Carin Berkowitz (2015) on the anatomical drawings of Charles Bell, Poskett (2015) on the publication and reception of Samuel George Morton's *Crania Americana* and Arminjon (2009/07/20) and Pogliano (2012) on Penfield's "homunculus" (drawn by Hortense Cantile) – one of the icons of 20th century neuroscience.

Twentieth century research on cellar neurobiology developed in many different directions, in tandem with discoveries in genetics and the invention of electron microscopy which made possible the detailed imaging of nano-scale structures such as the synapse (Shepherd 2010: chaps. 2 and 5). The discovery of neural growth factor in the 1940's by Rita Levi-Montalcini forms a fascinating story of experimental science taking place in the most adverse circumstances. The first stage of research, carried out on the nerves forming within chick embryos, took place in secret after the Mussolini regime banned Jews from holding research positions in Italian universities, with the underground laboratory moving a number of times in order to avoid the Nazi occupation. Subsequent research took place in Washington University in St. Louis, and had a wide impact on the understanding of diseases not only of the nervous system (Chao, Cattaneo, and Mobley 2013).

4.3 Medicine and the Nervous System

Much of the scientific research that I have included within the scope of the history of the neurosciences was performed by individuals whose primary training was in medicine or surgery, and who practised as doctors. To take some examples, Charles Bell was a surgeon, while Hughlings Jackson was a practicing neurologist and wrote about the different needs of theoretical and medical science, regarding classificatory systems (Chirimuuta 2017); Helmholtz trained originally as a physician, but contributed also to physics and psychology ("physiological optics"). For this reason, there is much scholarship on the history of medicine that is relevant to our topic. The specialities of neurology and neurosurgery all have rich literatures concerning their disciplinary formation, within various geographical locations. I will mention a small sample of these.[5]

[5] I have omitted discussion of work on the history of psychiatry and clinical psychology, though much in this literature is relevant to the history of the neurosciences. See for example essays in Wallace IV and Gach (2008), and references therein.

The historical writing on 19th century neurology has tended to be centred on the "flagship" hospitals of that era. The National Hospital for Diseases of the Nervous System including Paralysis and Epilepsy at Queen's Square in London was founded in 1859 and was the workplace of a number of well-known neurologists, including Hughlings Jackson, Charles Brown-Séquard, Henry Head, and Francis Walshe. A monograph by Lekka (2015) brings to light the patients' experience of the institution, whereas *The Neurologists* by Casper (2014b) focuses on the forging of the neurological specialist's identity. On the other side of the Channel, the Salpêtrière Hospital was renowned for Jean-Martin Charcot's Tuesday lectures in which patients, typically women suffering from "hysteria" were presented to curious members of Parisian high society. Didi-Huberman (2003) offers a rich account of this phenomenon, with express interest in the photographic iconography that developed around Charcot's work. An institutional history of neurology and related disciplines in Germany, during the late 19th century, is provided by Guenther (2015).

Moving into the early twentieth century, many of the famous cases published by neurologists were studies of war veterans. Following the Russo-Japanese war of 1904-05, the ophthalmologist Tatsuji Inouye produced the first retinotopic map of the primary visual cortex, through observations of the visual field defects resulting from bullet wounds to this brain area (Glickstein 2014: 130-2). Geroulanos and Meyers (2016) compare the investigations of Henry Head and Kurt Goldstein in the years following the first world war, with a focus on the condition of aphasia. The case studies of Head and Goldstein were notable for their impact on contemporary philosophers (primary publications include Head (1920) and Goldstein (1942)). Most frequently discussed is the phenomenologist Maurice Merleau Ponty's notion of the "body schema" [*le schema corporel*], derived from Head and Holmes (Paterson 2018), and his extensive discussion of Gelb and Goldstein's case study of the veteran, Schneider (Merleau-Ponty 1945/2004: Pt. 1, chapter 3). Similarly, Ernst Cassirer (1929/1957) devotes around one hundred pages of his *Phenomenology of Knowledge* to a discussion of the findings of Head, Goldstein and other neurologists. In case studies such as Gelb and Goldstein (1925), the interpretation of their patients' symptoms as due to a deficit in the categorical attitudes or behaviours [*kategoriales Verhalten*] – the ability to understand how concrete objects stand in relation to abstract classes (e.g. of colours or tools) – bears important connections to Cassirer's "philosophy of symbolic forms" (Métraux 1999; Matherne 2014).

The discipline of neurosurgery began to form in the early twentieth century. Greenblatt and Smith (1997) relate the contributions of Harvey Cushing at the start of the century, who was based at Johns Hopkins and later Harvard University. Foerster's development of surgical remedies for Little's Disease (a disabling paediatric disease) and *tabes dorsalis* (a condition of tertiary syphilis, affecting the spinal cord) are discussed in detail by Guenther (2015: chapter 4). Foerster was an early collaborator with Wilder Penfield on the surgical removal of cerebral scar tissue as a treatment for epilepsy. Penfield's contributions to neurosurgery, and to the iconography of neuroscience (as mentioned at the end of Section 4.2), are very much intertwined with the history of the Montreal Neurological Institute. This clinical and research setting are given a detailed depiction in the "biography" of the institute by Feindel and LeBlanc (2016). Another luminary of the MNI is Brenda Milner, whose case study of the post-operative amnesiac H.M., and discovery of the dissociation between episodic and procedural memory is often credited as a founding moment for the discipline of cognitive neuroscience (Zatorre 2018). Shepherd (2010: chapter 12) also discusses the work of Milner, and the McGill psychologist, Donald Hebb, whose theory of neuronal plasticity ("Hebbian learning") has also been foundational to current cognitive neuroscience.

5. Neurosciences, Mind and Society

In this last section I offer an overview of research that seeks to understand the history of neuroscientific ideas and practices in terms of wider social trends such as the dissemination of new technologies, the various prejudices against marginalised groups, and changes in more abstract philosophical views about the nature of human subjectivity.

5.1 The Brain and Discrimination

S. J. Gould's (1996) *The Mismeasure of Man* is still a valuable reference point on this topic as it offers a comprehensive view on how craniometry in the mid 19th century – in particular, the measurement of skull volume – was undertaken in order to establish a biological basis for the supposed inferiority of various groups. Targeted groups included non-white peoples, especially the indigenous nations of America, whose skulls were the subject matter of Morton's *Crania Americana* of 1839 (Poskett 2015), women and members of the economic underclass within Europe, deemed to be criminal and "degenerate". It should not be forgotten that major figures within the history of science, not only Paul Broca, but also Georges Cuvier and Francis Galton, are the protagonists here. This dimension of Broca's research on the brain is more often than not omitted or skirted over in historical accounts elsewhere, which focus primarily on his localisation of the speech defect. One finds this tendency, for example, in LaPointe (2014). Finger (2000: chapter 10) does write about Broca's involvement debates over the relationship between brain size and intelligence but presents Broca in a far more favourable light than does Gould (1996) – where quotations from Broca (1873) speak for themselves.

One of Gould's theses is that Morton's expectation that there would be a systematic difference in the skull volume across the races led him unconsciously to distort the measurements he made of his collection of human skulls. Lewis et al. (2011) attempted to vindicate Morton by re-measuring half of the skulls from Morton's original set, and by arguing that Gould, not Morton, was guilty of unconscious bias in his statistical analysis of Morton's findings. Subsequently, Kaplan, Pigliucci, and Banta (2015) have argued that while there were flaws in Gould's methods, the errors in Morton's dataset and logic of investigation loom even larger, such that Morton is in no way vindicated. In addition, Weisberg and Paul (2016) have proposed that Lewis and co-authors failed to address the substance of Gould's claims, invalidating their project entirely.

A matter that deserves further discussion is the relationship between phrenology and the biological-determinist argument employed by Samuel Morton and scrutinized by S. J. Gould. The appendix to *Crania Americana* is a an essay by the prominent British phrenologist, George Combe, entitled "Phrenological Remarks on the relation between the natural Talents and Dispositions of Nations, and the Developments of their Brains." Combe (1839: 270-71) argues, against Dugald Stewart, that the different "races" of humans are not uniformly endowed with mental capacities, and that climatic and other environmental circumstances cannot account for the variable manifestations of human civilisation.

As Combe puts it, the hard data of craniometry offer a more satisfactory, biological explanation of the irrepressible disposition of Europeans towards civilisation, industry and conquest, in contrast to the chronic state of barbarity of the nations of America and Africa, and the plateauing level of achievement to be found in Asia:

> The phrenologist is not satisfied with these common [environmental] theories of national character; he has observed that a particular size and form of brain is the invariable concomitant of particular dispositions and talents, and that this fact holds good in the case of nations as well as of individuals.
>
> If this view be correct, a knowledge of the size of the brain, and the proportions of its different parts, in the different varieties of the human race, will be the key to a correct appreciation of the differences in their natural mental endowments, on which external circumstances act only as modifying influences. (Combe 1839: 274)

A corollary of the biological-determinist naturalisation of cultural difference is the exclusion of the uncivilised peoples from conceptualisation as properly human, and their co-categorisation with the flora and fauna of the non-human, primeval wild spaces whose territory is retreating with the advance of Europeans. Combe quotes approvingly an unnamed writer for the Edinburgh Review:

> "it now seems certain that the North American Indians, like the bears and wolves, are destined to flee at the approach of civilised man, and to fall before his renovating hand, and disappear from the face of the earth along with those ancient forests which alone afford them sustenance and shelter." (Combe 1839: 272)

5.2 Technology In and Around the Neurosciences

It is often commented that the theoretical concepts at play in neuroscience are no more than mirrors of whatever technology is currently most advanced and impressive – from the hydraulically operated statues described by Descartes (Riskin 2016: chapter 2), and the telegraphy that proliferated from the 1850's (Otis 2002; Schmidgen 2003; Lenoir 1994), to the digital computers following the second world war. While computational neuroscientists Daugman (2001) and Eliasmith (2003) consider the history of the obsolescence of such technological analogies in order to advise caution regarding the current computational framework, scholars such as Borck (2012) have examined the matter as a case study in how the production and use of tools shapes human self-conception, and the theorisation of biological systems (cf. Canguilhem 1965/2008b).

Various studies have examined the issue of the transfer of technologies from other domains into neuroscience. This is of particular importance with respect to technologies for measuring the electrical activity of peripheral nerves or neurons, and forms of imaging that trace neural activity indirectly such as PET, fMRI and EEG (Borck 2008). Finkelstein (2013) provides detailed accounts of the efforts of du Bois-Reymond, along with the technicians and artisans whose skills were indispensable to laboratory research, to create a moving coil galvanometer sensitive enough to detect the tiny currents of electricity intrinsic to the nerves of dissected frogs' legs, thus proving the existence of "animal electricity". In addition, Dierig (2006) examines the material circumstances within the rapidly-industrialising city of Berlin as the backdrop to du Bois-Reymond's experimental activity. As a result of these observations, du Bois-Reymond is often named the discoverer of the "action potential" (e.g. López-Muñoz and Alamo 2009), but such terminology was not current in his time. Frank (1994) gives an account of the technological developments coincident with the emergence of the action potential concept and "all-or-none principle" of nervous transmission during the first three decades of the twentieth century. Similarly, with a focus on post WW1 England, Garson (2015) argues that the wartime development of vacuum tube technology was the key innovation behind research in the 1920's in Lord Adrian's laboratory, which generated visualisations of the electrical activity of nerves.

In comparison to Helmholtz (see e.g. Cahan 1993), however, little has been written on du Bois-Reymond, and none of his works have been translated into English since his lifetime. The magnum opus *Untersuchungen über tierische Elektricität* (volumes published between 1848 and 1884) was not translated into English other than a brief abstract. The public lectures are a rich source for studies of the emerging scientific culture in Western Europe (du Bois-Reymond 1912), but have received less scholarly attention than equivalent works by Helmholtz (e.g. Helmholtz 1995) and the majority are untranslated. Regarding Helmholtz and his collaborators, one should note Hennig Schmidgen's accounts of the development of experimental procedures to measure the time course of nervous activity, looking both at the interdisciplinary context – spanning industrial instrument making, astronomy, physiology and psychology – in which the relevant instruments were developed, and the cultural impact that such experiments made. Schmidgen (2003) focuses on Wilhelm Wundt, the student of Helmholtz, often referred to as a founding figure of experimental psychology. His account is a response to that of Schaffer (1988) who had argued, against Boring (1961), that astronomers had resolved the matter of the "personal equation" (the individual variability in observation of the time of astronomical events) independently of research by psychologists. *Die Helmholtz-Kurven* (Schmidgen 2009, 2014a) takes up the subject of Helmholtz's experiments on the speed of nervous transmission, showing how the concept of "lost time" connects Helmholtz with the novels of Marcel Proust. The connection between physiology and turn of the century aesthetics is a theme also pursued by Robert Brain (2015) in *The Pulse of Modernism*.

5.3 The Brain as the Self

The history of brain science is very much entangled with the history of conceptions of the mind. It is therefore not surprising that some of the influential early histories of brain science were written by professors of psychology (e.g. James 1890; Boring 1950). A number of social scientists, such as Jessica Pykett (2015),[6] have commented on the increasing

[6] See also essays in the volume *Critical Neuroscience* edited by Choudhury and Slaby (2012).

"neurofication" of discourses regarding human identity, behaviour, and governance. In conjunction with the observation of this phenomenon in its current guise, some scholars have attempted to trace the historical path of this trend. An important work here is *Homo Cerebralis* by Michael Hagner (2000). Hagner's central historiographical distinction is between the concept of the "organ of the soul" – the post-Cartesian notion (operative up to the end of the 18th century) of the brain as the organ by means of which the soul manifests its control of the body – and the brain, in its more familiar guise (from the early 19th century onwards) as the lump of matter which by itself "secretes thought". While one is reminded here of Carl Vogt's infamous saying that, "thought is to the brain what the bile is to the liver, or the urine to the kidneys," a strand of materialist thought amongst those discussed by Charles Wolfe (2016: chapter 6), Hagner's distinction should not simply be taken for a contrast between dualist and materialist theories of the mind; for Hagner argues that the replacement of a unitary self with a mind fragmented into distinct capacities is more significant than the question of the substance of the mind (p.20). The publication in 1796 of *Über das Organ der Seele* by Samuel Sömmering is presented as the inflection point between these two conceptions of the cerebrum,[7] with Franz Joseph Gall as the first representative and populariser of the new tradition.

Vidal and Ortega (2017: chapter 1) present a "genealogy of the cerebral subject" in which John Locke's theory of personal identity, presented in the *Essay Concerning Human Understanding* of 1694 is the founding conception of the human subject which makes possible the later identification of the person with his or her brain. This is an interesting proposal which hopefully will be explored by historians in the near future, though it should be noted that Bassiri (2016) has already argued that the fractured notion of personal identity to be gleaned from Hughlings Jackson's account of brain pathology is the *opposite* of the Lockean one. The essays collected in Bates and Bassiri (2016) provide a wide range of angles on the topic of the historical formation of the "neural subject", with one unifying theme being that if one considers the way that responses to the phenomena of neuropathology and neuroplasticity have shaped conceptual developments, the arc of the story is not simply that of a triumph of reductionism.

[7] Cf. Pecere (2016) on Immanuel Kant's response to Sömmering.

6. Future Directions

The historiography of the neurosciences is currently about as diverse in its foci of interest and methods of investigation as the neurosciences, past and present, themselves are. For that reason it is hard to determine specific trends or norms within the discipline, except to say that patient centred studies are now well represented alongside the traditional practitioner focussed ones, and that institutional histories make up a large proportion of the current scholarly output. Many topics remain under explored, and it would be a positive development to see the history of the neurosciences further integrated into ongoing debates within the history of biology and medicine. More specifically, an important direction for future research would be an investigation of any connections between decline of the reflex theory in the early decades of the twentieth and the subsequent rise of the computational theory after WW2. One connecting thread between these two quite general frameworks for theorising neural operations is the concept of "representation". As I have argued, Hughlings Jackson's introduction of the notion of "representation", in the context of the reflex theory, facilitated a synthesis between two naturally antagonistic views of the nervous system – a mechanistic or reductionist one, and a holistic one in which the function of motor regions of the cortex is to co-ordinate the movements of the entire body, requiring a global integration of "information", and a high degree of context-sensitivity (Chirimuuta forthcoming). It is plausible that the concept of neural representation, later deployed by computational theorists, has a similarly synthetic nature. In other words, that it fills some explanatory gap – regarding the neuronal basis for the integration of sensory information and coordination of behaviour – that would be left under an exclusively biomolecular approach to experimental neuroscience, an approach made popular with the development of tools for performing local and precise interventions on neural tissue. This line of investigation invites comparison with the rise of informational thinking within biology that coincided with the "molecularization" of the discipline following the discovery of DNA (Kay 2000).

Acknowledgments

I would like to thank JP Gamboa for providing detailed comments on the literature on cerebral localisation, and Mark Paterson both for comments and for numerous conversations prior to the writing of this chapter. I am also grateful to the editors of this volume for their help and suggestions.

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