Political Neurons: the Visualization of the Functional Brain and the Economies of Order in 19th Century

Nuria Valverde (PhD, UAM-Cuajimalpa)

> '¡Quién diría que la nube y el pájaro, que el río y el ferro-carril caminan por virtud del mismo impulso, que no existen diferencias esenciales y son hijos de la misma energía el calor del rayo solar que besa nuestra frente y la callada agitación del pensamiento que palpita en las células de nuestro cerebro!'
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> S. Ramon y Cajal, 'Sobre los *Prolegómenos de Anatomía* de Salustiano Fernández de la Vega', en *La Clínica* (Zaragoza) 279:51-52 (18/02/1883) en Cajal (2001: 74).

> 'I hail with joy the oceanic, variegated, intense practical energy,the demand for facts, even the bussiness materialism of the current age, our States. But woe to the age or land in which these things, movements, stopping at themselves, do no tend to ideas. As fuel to flame, and flame to the heavens, so must wealth, science, materialism -even this democracy of which we make so much- unerringly feed the highest mind, the soul.'
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> Walter Whitman, 'Democratic Vistas' [1867] (cit. in Schultz, 2004: 604)

Images play an important role in defining the kind of agency, the kind of power we attribute to individuals. Thus, when they are images of parts or components of a complex they often require to be read in a context of political expectations. The aim of this work is to explore how during the 19th century neurological disciplines developed visual strategies that did not only lead to different theoretical implications —as the directionality of the nerve impulse in the nerve cell— but fostered different ways of reading the political landscape (under the concept of system). It focuses on how the Spanish and British interpretations of the nervous system were related with different justifications for the political systems that most fitted their political circumstances; respectively, a dissolved Empire, like the Spanish Empire at the end of the 19th century, in search of a new future; and a well established one, the English Empire, looking forward to long-standing unity. Here political imagination meets systemic imagination.

Neurons and Cantons

During 19th century neural and social processes, from the point of view of dynamics, began somehow to mirror each other. At times, this effect became more evident. Most contemporary readers of Santiago Ramón y Cajal (1852-1934), reading on his theory about the discrete neural structure of the brain, were surely aware of the political implications behind his definition of a neuron as 'an absolutely autonomous physiological canton'.

The so-called 'cantonal insurrection' that took place in 1874 was caused by the destitution of Francisco Pi y Margall (1824-1901) as President of the First Spanish Republic (1873-1874), and the subsequent conservative turn in the republican government. Almost immediately a number of localities —mainly in the regions of Valencia, Murcia and Andalusia — declared themselves independent cantons or republics. Some of them even declared war on the central State or on other cantons; and for some politicians of the time the cantonal

movement was one of the main causes of the failure of the Republic. Since then, the question of how to harmonize —and at what cost— local and regional interests with central government interests and economic regeneration would be at the core of Spanish liberal politics. Thus, the connection between the structure of the brain and organizational problems in the political realm was probably quite clear for Cajal's Spanish readers.

Just before Cajal produced his neuronal theory, John Seeley, who was by then history professor at the University of Cambridge, published *The Expansion of England* (1883), a book that signalled a turn in thinking about the Empire as a federal form of Imperial government. The thought that progress —the conjoint process of growth and civilization— was a collaborative enterprise that tends to produce more complex —and heterogeneous— social systems led to the conviction that federalism was the natural tendency of political societies. Some aspects of this discussion entered the neurological field long before 1906, when Santiago Ramón y Cajal and Camillo Golgi received the Nobel Prize for their neurohistological staining technology.

By 1888, the task of visualizing this nerve architecture and the directions of its connections through histological images implied being able to create a sequence of growth. Embryo histology helped in providing that timing sequence, specially since Golgi-Cajal's staining procedure worked better upon non-myelinated –so to speak immature fibres– than on myelinated fibers –a mature fibre and a well established nerve current. **(fig. 1)**

Tissue of embryos and very young animals faced histologists –and specially Cajal, who made an extensive use of it– with the question: "what is gained and lost in the process of maturation of the nerve cell?" At a neuronal level, connectivity was not just a inherent part of the process of growth, but the main factor in defining growth, so the answer was clear:

maturity was a disposition to enhance connection to others. The point was how to ascertain the nature of that connection. What kind of limits does the structure of the unit impose on the configuration of the whole?

One of the main and first theoretical contributions of Cajal's work was the demonstration of the conductive role of both dendrites and soma in his 1888 paper 'Estructura de los centros nerviosos de las aves'. A year later, he suggested the directionality of the nerve impulse (dentritas-> soma -> axon) **(fig. 2)**, that was more neatly formulated in 1891 as the 'hypothesis of the dynamic polarization of the nerve cell'. But Cajal's conception of the architecture of the nervous system was also rooted in his own beliefs about the power of the will to modify one's own cerebral structure and, thus, to control ones own fate. So Cajal was focusing not as much in the nature of the flux as on the possibilities of cells in establishing and reshaping connections.

Inhibition and Collective Action

By those years, the Neurological Society of London, founded in 1886 by John Hughlings Jackson (1835-1911) began to debate notions about processes as attention or inhibition, or in other words, will and voluntary movements and unconscious control. Following Jackson's understanding of the epileptic fit, notions of control and personal integrity were constructed considering the nervous system as a hierarchical and closed system where less complex parts were controlled by more complex instances. A proper flow of energy or the chaotic release of it made the difference between a state of normalcy and complexity, or a pathological one, or of loss of complexity. There were some reasons to be dissatisfied with this model: first, it was unclear what role was played by external stimuli, and also by the processes of learning and positive/negative response to environmental stimuli; second, it failed

to explain collective intentionality and/or the role of the will in collective actions (e.g., military action); and third, it did not make clear why in a complex neural organization energy release had to be hierarchically, instead of being such control operated at the cellular and inter-cellular level. **(fig. 3)**

In any case, the two poles of the discussion about supra-individual behaviour (e.g. army corps) and cellular behaviour shared the same concern: what was behind collective action and cooperation between parts when it was not enforced by structural links —hence, when the parts enjoyed a relevant degree of autonomy? Five years later, the question was revisited.

Dynamic Polarization and the Question of Physiological Continuity

In 1893 the Presidential Address of the Neurological Society faced for the first time the question of the new role of the elementary units of the brain. Edward Albert Schäfer (1850-1935), Fellow of the Royal Society and Jodrell Professor at the University College of London, delivered the lecture 'The nerve cell considered as the basis of neurology'.

In this paper Schäfer rejected Cajal's idea of dynamic polarization arguing that nerve impulses can pass through the cell in any direction. Two years before Francis Gotch and Victor Horsley had demonstrated that 'nerve-impulses pass very readily from the nerve-centre down the afferent channels, although the strongest excitation will not cause them to pass from the efferent channels up the spinal cord'. Schäfer's was an attempt to answer the question: What was the reason of this selective blocking of the direction of the nerve impulse?, without compromising physiological continuity.

Inserting electrodes in the cortex to measure and record with a galvanometer the intensity of the impulse as it passed through the cord of a cat, Gotch and Horsley discovered

that ‘the physiological characters of the structure upon which the storage of energy depends, are such as to be rendered more efficacious with use’. Also, they suggested that the amount of resting difference indicates the amount of potential energy that the nerve material was capable of transforming in kinetic energy ‘in the form of a nerve impulse’. Each cell was therefore able to administrate an amount of energy. Finally, their work corroborated that the connection between nerve fibers did not mean a passage of nerve impulse. There was no ‘freedom of circulation’ susceptible of being controlled by a superior order, but (degrees of) resistance. They seemed also to support the idea that release of energy was controlled at the neuronal level, and to some extent their approach matched Cajal's theory of dynamic polarization.

The idea that paths, although not immediately and effortlessly reversed, were bidirectional fostered new explanations about the structural and dynamic consequences of this fact. When Schäfer decided to analyze the question of the unidirectionality of the centrifugal [i.e., efferent or motor] paths of nerve impulses, he took Gotch and Horsley records as the starting point to deduce some of the dynamic aspects of the nervous system while avoiding presuppositions about substantial structural differences between afferent and efferent nerve cells. **(fig. 4)**

He realized that the changes of rhythms and intensities recorded by the graphs could be easily explained if nerve cells were considered to be autonomous; if nerve impulses were produced by the contraction of nerve-cells in a rhythmic sequence. However, each transit of the nerve impulse from one nerve cell to another implied a conversion into new nerve-impulses ‘that may have a very much less frequent rhythm’. Clearly, the communication between cells failed if the wave-like nervous impulse diffused in the cell body, becoming too weak to induce a change of rhythm in the next cell. This was what he supposed was blocking

the way backwards of the normal efferent (motor) paths (**fig. 5**). Thus, it was not the position of the cell that determined the flow of the nerve impulse, but the possibility of detecting a different nerve impulse, a degree of intensity beyond a threshold. So, neurons weren't autonomous physiological cantons, they needed an external cause to make a start, and the stimulus could begin at any point in the cell and take any direction. Neurons were bidirectional or physiologically continuous.

In this context, rhythm offered a visual response to the question of what kept neurons working together. As opposed to Cajal's histological representation of the nervous flow as immediately canalized by the nerve cell; rhythm was thought to recover nerve impulse as a constant, all pervading, never ending, intensity fluctuating, flux. Shäfer saw changes of rhythms as the effect of a continuous detection and emission of nerve impulses; an infinite labour of emission and translation.

Three years later, it was the turn for Alexander Hill (1856-1929) —by then Master of Downing College at Cambridge, president of the Neurological Society of London and Vice-chancellor of Cambridge University— to criticize Golgi's method and Cajal's conclusions. His presidential lecture dealt with the diagrammatic character and limitations of Golgi's method and hence with the weakness of the evidence in support of the neuronal theory. He distrusted the characteristic selectivity of the crome-silver method because 'the thought which a good Golgi-preparation [...] suggests is not, how complete the picture [is], but how much there must be that one does not see!'. This pattern of offering information was the opposite to that provided by theories. Gerlach's network theory (also called "reticularism", opposed to "neuronism"), for example, allowed us to '*see* the impulses which had sunk out of consciousness taking a dynamic attitude within the cells in which they had lain dormant, and

starting on a fresh voyage through the network, *coming into relation with other impulses similarly liberated*--- combining, disparting, interweaving the tissue of a dream or a thought'. If one renounces to this conception –he stated- the brain, as a mechanism, becomes unthinkable, *for it bears no relation in character to the products of its own activity*.'

In subsequent papers, Hill would emphasize the point that Golgi-Cajal's method hardly served to contest the existence of continuous circuits that connected different kinds of nerve elements when it rarely stained two distinct kinds of nerve elements. However, and despite all his efforts to offer models that preserved functional continuity as an strategy for defining different mental processes (as attention and inhibition) as opposite ends of a system based on graduation and equilibrium, Hill did not *exactly* deny the neuronal theory in this lecture or in subsequent papers.

As Schäfer, Hill considered the nervous system as physiologically continuous and structurally discontinuous. But Schäfer's approach was unclear on defining the limits of nerve cell autonomy; his stress on physiological continuity made structural discontinuity appear as a circumstance that did not to pose any problem in the overall economy of the nervous system. Hill was instead more committed, as Ramón y Cajal, with a territorial analogy.

'Composite States': Nurture, Resources and Unanchorages

If Cajal compared neurons with cantons, Hill explained the limits of nerve cell autonomy this way:

> 'Each nucleus is therefore the capital of a cell territory. Whether or not the economic processes carried out within the territory are in any way controlled from the capital, it is quite certain that each territory is self-governing [...] Each individual cell grows, carries on the business of its life, and dies, as a unit'

It was discontinuous in the nutritional or metabolic plane, it was continuous in terms of flows of energy (the economic processes). Again we have an effort to separate the dynamics of the nervous system from the life of the autonomous cell. Behind this consideration about the independence of the functional aspects of the whole in relation to the metabolic autonomy of the nerve cell was the defence of a certain notion of Empire.

As a professor, Hill had a deep interest in pedagogy. In 1897 he published a book titled *A Run Round the Empire*. As the subtitle reads, the book was a report or log of two young people that circumnavigated the globe to improve their knowledge of the English empire. The editor hoped that 'even so slight a sketch of the British Empire would help our fellow-subjects to realize the wealth of their heritage; although no one who spends his life between Land's End and John O'Groats can fully appreciate the immense resources of his native country'.

This heritage was the core of the book's story. By describing the history of the different colonies that were part of the English Empire, Hill tried to grasp the essence of the Imperial unity, the essence of heritage. Thus he reviewed the history of the integration of each colony into the Empire highlighting the inflow of resources from the metropolis. Referring to Australia, for example, he says: 'it is difficult to see how, without forced labour, the colonies could have made so good start' (p. 96); he talks about Ceylon in similar ways, affirming, for example: "Ceylon is a remarkable illustration of what British enterprise and order can do for a native race" (p. 70). Along the text, heritage emerged basically in the act of providing the resources that allowed each colony to make a new start each time (within the system). As any nerve cell each state grew and died as a unity. But they could not have any initiative, make a start by themselves nor make substantial changes in the behaviour of the whole on their own.

Because only through those pieces of history and descriptions of the colonies could the essence of what was an empire, what kept it united and made it a whole, be captured, the conclusion could not be other than this:

> 'The natural boundaries of an empire are not fixed by areas of race, language or religion; else would the British Empire be a singularly incoherent collection of states'. **(fig. 6)**

This statement remind another one done by Seeley in the introduction to *The Expansion of England*: 'our Empire is not an Empire at all in the ordinary sense of the word. It does not consist of a congeries of nations held together by force, but in the main of one nation, as much as if it were no Empire but an ordinary state'.

In 1897 Cajal wrote a paper where he gave an interesting interpretation of Herbert Spencer's 1857 paper 'Progress: Its Law and Causes'. He stated that Spencer's integration law explained that nervous systems were constructed in order to save protoplasm and faster transmissions. Each single cell deploys this economy that supported the success of the nerve system as a whole. Certainly, on the edge of the Spanish-American war of 1898, when Spain definitively lost the last traces of his empire, it was worth believing that a new start was possible if one could forget the old long-distance flows and begin to trust individual forces for creating new connections that eventually would lead to new ways of growth.

The common rules of growth and civilization and the common individual principles of growth and regeneration were thus constructed as a separate set of rules in the realm of neurology both as a consequence of the limits of different visual technologies and as a response to the need to perpetuate or break with historical and political constrictions that defined the essence of political unity.