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# Introduction: cerebral cartography 1905–2005

As a pejorative term, 'cerebral cartography' is surpassed only by the now commonly used 'new phrenology', to stigmatize current efforts to assign specific functions to specific cortical areas. This effort is not new, although it has seen something of a renaissance since the advent of human brain imaging studies. It has its origins in the work of Pierre Paul Broca and Fritsch and Hitzig who, between them, showed that cerebral areas of distinct histological appearance—the third convolution of the left frontal lobe and the motor cortex—have distinct functions, that of producing articulate speech and of initiating movement, respectively. However, it can be said to have acquired renewed vigour in 1905, which saw the publication of a major treatise by Alfred W. Campbell, *Histological Studies of Cerebral Function* (Campbell 1905) and a major paper by Korbinian Brodmann in the *Journal fur Psychologie und Neurologie* (Brodmann 1905). Both had used the then relatively new Nissl method to study the cytoarchitecture of the cerebral cortex. To this list must be added an article by Paul Flechsig, also in 1905, in which he summarized his myelogenetic studies, which had shown that certain parts of the cerebral cortex (the primary areas) have a mature myeloarchitecture at birth, while others (associational areas) acquire their mature appearance at various stages after birth (Flechsig 1905). This cartographic approach ushered in what Donald Sholl described as an 'era of feverish map-making'. But it was short-lived, or so it seemed. It had powerful detractors, perhaps best seen in the article by Lashley and Clark, in which they questioned not only the method of cytoarchitectonics but all architectonic studies and their aims as well (Lashley & Clark 1946). Soon cyto- and myeloarchitectonic parcellations ceased to dominate research into the cerebral cortex.

Yet the very use of the term 'new phrenology', even today, is perhaps eloquent testimony to the power and survival of one of the main themes of cortical studies, perhaps the main theme, namely the attempt to assign specific functions to regions, areas or subareas of distinctive architecture. As the results of human brain imaging studies continue to show (Wandell *et al.* 2005), the approach remains a highly successful one. Indeed, to the cytoarchitectonic and myeloarchitectonic maps one can now add a new kind of map based on time, the chronoarchitectonic map, which also shows many more subdivisions than the early cartographers could have imagined (Bartels & Zeki 2005). Moreover, new methods are being developed to localize functions in cerebral areas (Kötter & Wanke 2005). Nor can the hate term 'new phrenology' be restricted to imaging studies alone. Anatomical and physiological studies have been equally successful in demarcating areas and subareas (Rosa & Tweedale 2005; Gattass *et al.* 2005; Kaas *et al.* 2005) and have indeed shown, far more effectively even than human imaging studies, that the parcellations proposed by the early cartographers were timid and modest, compared with the many more subdivisions that more recent approaches have revealed. Brodmann, Campbell and Flechsig would be surprised by the number of subdivisions in the cerebral cortex. This issue of *Philosophical Transactions* is really a celebration of that major theme in cortical studies rather than the achievements of the early cartographers or the 'new phrenologists', impressive though these were and are. As always, throughout the history of cortical studies, subdivisions have raised the question of functional significance. This trend has seemingly remained unchanged (Horton & Adams 2005). Moreover, issues of hierarchy, emphasized by Campbell (1905) and Flechsig (1905) continue to play a role in thinking about cerebral organization (Friston 2005). And the underlying causes for the pattern of lamination and differences in lamination between cortical areas, continue to attract attention (Shipp 2005).

It is perhaps odd that, over a century after the initiation of cartographic studies, we still commonly use the nomenclature of Brodmann to describe cortical areas demonstrated by imaging studies. This solves two problems at once: it gives the impression that a brain area has been identified and saves us from the trouble of enquiring more deeply into the extent and limits of the area. The use of this early nomenclature is not so much a tribute to Brodmann or Campbell, whose subdivisions are, as stated above, modest compared with the new ones. In the macaque monkey, an area such as area 18 of Brodmann can now be subdivided into at least four areas, making the term 'area 18' obsolete. Furthermore, the current subdivisions in the frontal lobe are not entirely consistent with Brodmann's subdivisions (Petrides 2005). That we continue to use the early nomenclature reflects in part the inadequacy, because of limited spatial resolution, of imaging methods to subdivide the cortex in the way that anatomical and physiological studies can. It reflects in part, too, an obvious, although possibly unwelcome, fact: that most practitioners of imaging methods today are impatient with anatomical and microscopic studies and have therefore been reluctant to supplement their imaging studies with histological ones. This should not be taken as criticism. Currently, the means of studying the human brain histologically are very limited and the old and somewhat tedious architectonic methods have

One contribution of 12 to a Theme Issue 'Cerebral cartography 1905–2005'.

run their course and been pushed to their limits. The chances of finding new architectural subdivisions by their use is small and studies of connections have had limited success in the human brain. However, the early cartographers cannot be faulted for not trying to supplement their studies with work on connections. Campbell in particular, emphasized the importance of studying connections in the human brain, thus anticipating the current importance of such studies (ffytche 2005).

In spite of the enormous progress that has been made in the intervening century since the works by Brodmann, Campbell and others were published, it is clear that the basic premise of the early cartographers—that areas that differ in function will also differ in architecture—has turned out to be substantially correct. The profound issue of integration that early parcellation studies raised, and on account of which they were attacked, is rendered even more acute by the demonstration of so many new areas. If neurobiologists in the first 70 years of the last century worried about how visual signals are integrated with other sensory signals, their worries have been increased by an order of magnitude. Today we have to account for how visual signals belonging to one attribute, channelled to one cortical area, are integrated to visual signals channelled to another cortical area, before even considering how visual signals are integrated with other, nonvisual, signals.

Hence the search for areas has continued and will continue with the development of new architectonic methods, such as that of metabolic architecture. History continues, and repeats itself, in other ways too. The era of feverish map-making is, in a sense, with us again and there has been an enthusiasm for finding areas, even when logic and evidence speak against them (Zeki 2003). No doubt every new approach brings its excesses. However, it is interesting and wise to reflect that, after one century and huge progress, we are still grappling with the same problems as our predecessors of 100 years ago.

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