MEDICINE AND SOCIETY

Modelling the mind: the case of Warren S. McCulloch

The human brain is increasingly understood as an information processor. Metaphors of the brain as computer have dominated the cognitive sciences since the 1960s, and several branches of the neurosciences now use computational practices based on mathematical modelling. Most of these fields, such as theoretical neuroscience, are highly interdisciplinary. Computational modellers use mathematics and statistics to explore processes such as sensory perception and learning, and they argue that we need models to deal with the brain's complexity and the massive amounts of neuroscientific data generated by empirical researchers.[1] From the perspective of psychiatry, models also hold promise for advancing a brain-based approach to mental illness. Some even call for a computational psychiatry, with the aim of understanding mental illness in terms of irregular computational processes.[2]

American neuropsychiatrist and cybernetician Warren Sturgis McCulloch (1898–1969) typified this interdisciplinary mode of understanding the brain, and current researchers can point to McCulloch as a trailblazer. Trained in neurophysiology, McCulloch worked as a research psychiatrist during the 1940s and was a key architect of the American cybernetics movement, a transdisciplinary effort in the postwar era that used methods of the mathematical and engineering sciences to understand living systems, particularly in terms of communications, control and feedback. Involving collaborations across the divide between biomedicine and engineering, and drawing support from sources as diverse as the Josiah Macy Jr. Foundation and the US Office of Naval Research, cybernetics had far-reaching effects, including the expansion of Cold War information technologies.[3] McCulloch's brand of cybernetics used logic and mathematics to develop models of neural networks that embodied the functioning of the mind in the workings of the brain.[4]

What can we learn from McCulloch's story? Scientific biography can be used for more than worshipping a lost scientist. We can grasp important dimensions of scientific practice through McCulloch's life, in particular, to explore both the power and the challenge of interdisciplinary practices in biomedicine. Although McCulloch's work and modern theoretical neurosciences share important features, they emerged in different historical contexts and have faced different sorts of critiques.

McCulloch travelled through diverse disciplinary worlds throughout his scientific life.[5] He studied psychology at Yale University, graduating in 1921. After obtaining a master of arts in psychology and a medical degree from Columbia, McCulloch began research in experimental neurology and studied the areas of the brain responsible for epileptic seizures. After spending several years working at Bellevue Hospital in Manhattan and at the Rockland State Hospital for the Insane, he returned to Yale in 1934 to work in the neurophysiology laboratory of Johannes Dusser de Barenne. There, they probed the brain's functional organization, experimenting with primates. McCulloch studied the brain during an era when philanthropic agencies such as the Rockefeller Foundation poured massive amounts of funding into basic brain research in an attempt to ground psychiatry in laboratory science.

In 1941, McCulloch went to the University of Illinois to join the Illinois Neuropsychiatric Institute in Chicago. There, he collaborated with Ladislas J. Meduna on the relations between epilepsy and schizophrenia. They researched the mechanisms behind insulin shock therapy as a treatment for schizophrenia, on the basis of Meduna's erroneous belief that people with schizophrenia never developed epilepsy. At Illinois, McCulloch also became a brain modeller and cybernetician. He collaborated with Walter Pitts, a mathematician interested in logic and symbolization, on the logic of the central nervous system. In 1947, for example, Pitts and McCulloch presented a hypothetical model of the functional relations between neurons that achieved recognition of universal forms, such as the perception of the form "triangle" regardless of size or context (Figure 1).[6] The model was highly mathematical and ultimately was shown not to represent reality accurately. Eventually, McCulloch drifted away from direct involvement in psychiatry and in 1952 went to the Massachusetts Institute of Technology's multidisciplinary Research Laboratory of Electronics, where he spent the rest of his life addressing brain function within the framework of information processing.

McCulloch was always more at home in a laboratory than in a clinical setting. He believed that if psychiatry was to work, it had to be firmly rooted in the sciences of the brain. This belief was a response to the disciplinary cultures of mid–20th century American psychiatry: in the face of eclecticism and the rise of American psychoanalysis, McCulloch thought it was intellectually necessary — and strategically valuable — to promote a foundational framework for psychiatry based on models of the brain.

For McCulloch, disciplinary boundaries were meant to be crossed. Disciplines, to borrow a phrase from anthropologist Clifford Geertz, are ways of being in the world.[7] To practise science in a specific way is not simply to perform technical feats but to "take on a cultural frame that defines a great part of one's life."[7] Historically, these cultures are shaped by boundaries that can be blurred, for all sorts of reasons. Although the institutional settings of mid–20th

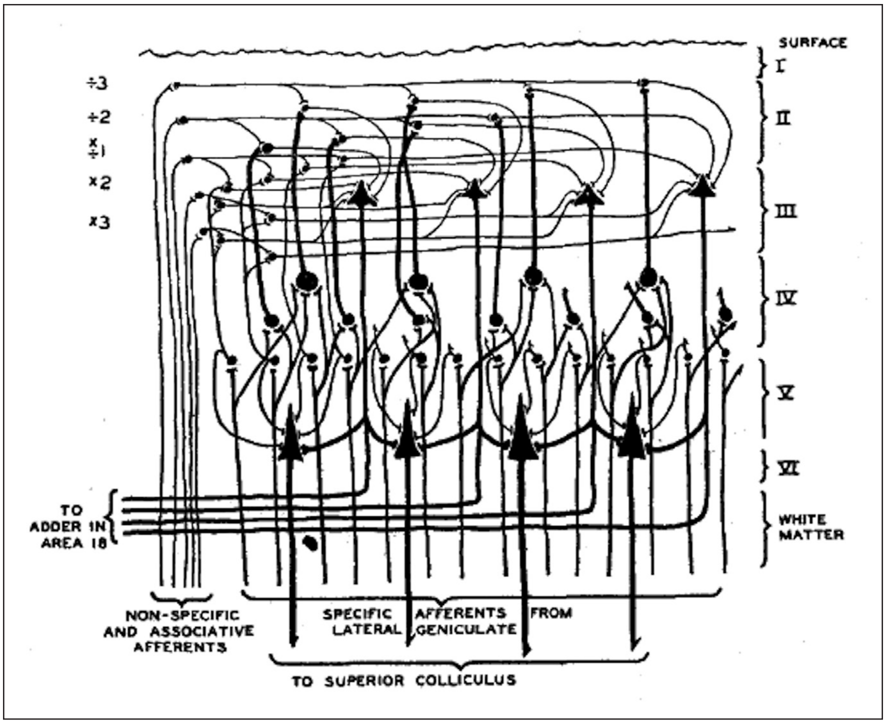

Figure 1: Pitts and McCulloch's model of the visual cortex. Impulses relayed by the lateral geniculate move down to layer IV, where they branch laterally and excite small cells singly and larger cells by summation. Large cells thus represent larger visual areas. From layer IV, impulses go to higher layers. From there, they converge on large cells of the third layer that relay impulses to the parastriate area 18. On their way down, they contribute to summation on the large pyramids of layer V, which relays them to the superior colliculus. Reproduced, with permission of Springer, from "How we know universals: the perception of auditory and visual forms" (W. Pitts and W.S. McCulloch),[6] *Bulletin of Mathematics and Biophysics* 1947;9:127-47. Copyright © 1947 University of Chicago Press.

century America helped shape McCulloch's varying identities and encouraged his role as a scientific traveller, he faced obstacles to his transdisciplinary project.

Critical responses to McCulloch often centred on his deliberately loose rhetorical style, in which terms from different disciplines were used in an ambiguous way to promote a unified view. Critics found McCulloch's rhetorics and models problematic. His models were also criticized for being too speculative and difficult to test empirically. McCulloch's models would likely not pass muster in current theoretical neurosciences, as they were highly abstract, employed vague language and had only a tenuous connection to psychiatric practice. Such were the costs of blurring disciplinary boundaries. Yet, although McCulloch's models failed to incorporate sufficient empiric data, he was still judged by his peers as a brilliant and inspiring figure who raised a crop of theoretically minded brain researchers and computationalists who have shaped the field.[5]

To be sure, McCulloch's disciplinary worlds were vastly different from those of today. Most of McCulloch's work as a neuropsychiatrist took place at a time when the boundaries among neurology, neurophysiology and psychiatry were fluid. In contrast, critics today lament the fact that neurology and psychiatry have evolved as arbitrarily disparate medical specialties.[8] Furthermore, McCulloch's search for foundations evolved during an era when science and philosophy were affiliated in different sorts of ways than they are now, and attempts were made to ground the biological and human sciences in the more rigorous practices of the physical sciences and mathematics.

Theoretical and computational neuroscience have evolved into distinct and thriving disciplines, with a joint funding program in the US National Institute of Mental Health. Yet their relevance to psychiatry remains problematic. Certainly, psychiatry still has its share of disciplinary woes. Most would agree that some sort of neurophysiological basis for psychiatric disorders is needed. Those who discuss the possibility of computational psychiatry argue that models can overcome the fragmented nature of the discipline and its lack of explanatory coherence, yet critics charge that computational models will never capture the subjective experiences encountered in clinical practice. More work will be needed to convince clinical psychiatrists that theoretical models will help them to navigate the messy world of clinical disorders, although modellers make much more effort than did McCulloch to bridge the gap between biology and psychiatry. Computational models of the brain are not always easily testable, nor are they easy for empirical researchers to understand. Furthermore, not everyone is convinced that to reform psychiatry we need more work on the brain. Such critics call for a more pragmatic approach to clinical practice, one that acknowledges the equally important roles of the social and the psychological in a person's mental health.[9] Whether or not computational models are able to capture this reality is an open question.

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