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COMMENTS ON *MODES OF FUNCTIONAL ORGANIZATION OF THE CEREBRAL CORTEX*

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This is a crucial paper in several ways. It stands in time almost exactly halfway between the first and the last paper Warren McCulloch wrote. It deals with the cerebral cortex, the central theme in McCulloch's neurological field of interest. It illustrates the mixture of critical knowledge and poetic expression that gives all of his papers that peculiar presocratic ring, which I find admirably balanced in this little review. The fusion of a vast number of references from over 100 papers into a coherent train of thought and a melodious flow of language constitutes a virtuoso performance. I suspect this was felt to be as much a challenge by McCulloch as the subject matter itself. In yet another way this article occupies a central place in McCulloch's production, namely in the historical sense, which places it between the two great periods of macroscopical neuroanatomy and the logic of neural networks. This is superficially contradicted by chronology because the *Logical Calculus of Ideas Immanent in Nervous Activity* was a 1943 paper.

The scientific history of those years fades in perspective into the wide spectrum of neurological activities today, and lo and behold again we find that the central questions today are the same as those that vibrate through McCulloch's review of 1947. There we are told that some authors place their emphasis on internal and external feedback circuits, while others prefer to think in terms of a unidirectional sensory or motor flow, and we are confronted with the problems posed by the numerical relations of input, output, and internal connections of the cortex. The areal parcellation of the cortex, apparently a pastime for anatomists, was grudgingly admitted by physiologists on the basis of their own findings then, and it is now again. Most surprising to us late

comers, as soon as the references which describe the synaptology of the cortex are collected, the radical difference between horizontal and vertical internal connections of the cortex is recognized, and to describe the latter, the concept and term "columns" is introduced for vertical chains of neurons, of which there are about one thousand in a square millimeter, quite like the finest hypothesized recently in the visual system. In one way the old review is ahead of us. It makes use of the facts collected to introduce a detailed model of pattern perception, with figure invariance and all. Nowadays the physiologists tend to wait for the engineers to do the thinking.