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Introduction

(1949)
Donald O. Hebb

The Organization of Behavior, New York: Wiley, Introduction and Chapter 4, "The first stage of perception: growth of the assembly," pp. xi–xix, 60–78

Donald O. Hebb's book, *The Organization of Behavior*, is famous among neural modelers because it was the first explicit statement of the physiological learning rule for synaptic modification that has since become known as the Hebb synapse. However, the book covers a great deal more material than that, and is a thoughtful and thorough review of neuropsychology, as of 1949.

We have included Hebb's Introduction in this excerpt. It is a brief and lucid discussion of the connection between psychology and physiology, and has not dated one bit between 1949 and now.

The introduction is also notable because in it is one of the first uses of the word "connectionism" in the context of a complex brain model. The final paragraph of the Introduction contains these lines: "The theory is evidently a form of connectionism, one of the switchboard variety, though it does not deal in direct connections between afferent and efferent pathways: not an 'S-R' psychology, if R means a *muscular* response. The connections serve rather to establish autonomous central activities, which then are the basis of further learning" (p. xix). Most modern day connectionists could find little to argue with in that summation.

A more detailed description of Hebb's physiological ideas is found in chapter 4. In this chapter, Hebb has a detailed discussion of neurophysiology and neuroanatomy as it relates to his ideas. It is worth emphasizing, if it is not obvious at this point, that the early modelers really knew their neuroscience. James, McCulloch, and Hebb were highly knowledgable about the nervous system, and used their knowledge extensively in their models. Much modern work in neural networks has moved far away from its roots in the study of the brain and psychology. This is a cause for concern, both because the field is losing contact with its foundations and because it has lost a source of valuable ideas.

Hebb suggests several important ideas in chapter 4. First, and most famous, was the clear statement of what has become known as the "Hebb" synapse. To restate Hebb's description, for the *n*th time, "*When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased*" (p. 50). This, like the other ideas in Hebb's book, is not a mathematical statement, though it is close to one. For example, Hebb does not discuss the various possible ways inhibition might enter the picture, or the quantitative learning rule that is being followed. This has meant that a number of sometimes quite different learning rules can legitimately be called "Hebb synapses." (Paper 6, an early computer simulation of Hebb's ideas, discusses the modifications one must make to this bare outline to make the system work.)

Second, Hebb is keenly aware of the "distributed" nature of the representation he is assuming the nervous system uses. The idea is that to represent something, many cells must participate in the representation. Hebb was aware of the work of Lashley (paper 5), suggesting widely distributed representations, and made some use of his ideas, though not in the strongest form of complete "equipotentiality."

Third, Hebb postulated the formation of what he called "cell assemblies," which were really the heart of the entire book. The basic idea was that there were interconnected, self-reinforcing subsets of neurons that formed the representations of information in the nervous system. Single cells might belong to more than one assembly, depending on the context. Multiple cell assemblies could be active at once, corresponding to complex perceptions or thoughts. There was a distributed representation at the functional level as well as at the anatomical level. Hebb devotes a good deal of attention to the details of the neuroanatomy and physiology that might underlie cell assemblies. The later chapters in the book contain many discussions of how cell assemblies can be used to help explain a number of psychological phenomena.

In retrospect, the idea that there exist temporarily stable, relatively long lasting neural activity patterns that are important in mental activity has reappeared in the various "attractor" models for brain activity (see, for example, Hopfield, paper 27; Grossberg, paper 24; or Anderson et al., paper 22). Details of the observed and predicted stability depend critically on learning assumptions that are nearly always based to some degree on Hebb synapses. Some of the ideas described in this book have become part of the accepted lore of the field.