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Book Review

Integrating Neural Functions

Neural Organization: Structure, Function, and Dynamics
By Michael A. Arbib, Peter Érdi, and János Szentágothai
Cambridge, MA: MIT Press (1998). 395 pp.

A recent addition to the folklore of brain modeling is the story of the extremely senior neuroscientist who stumbled across the board meeting of a new journal in this area. Uninvited, he offered the opinion that computational neuroscience had achieved nothing in the decade or so since its most recent incarnation, that the enterprise had therefore failed, and that it was time for computational neuroscientists to gracefully (or otherwise) retire to more productive pursuits. Whether or not this bleak assessment of the symptoms is accurate, it is unarguably true that a great many neuroscientists do not share this view of the cure. On the contrary, they see an increasingly important role for mathematical and computational theories in the design and interpretation of their experiments. This projection is rooted in the belief that all experiments rely on theories, however implicitly, and that making these theories explicit and quantitative can only serve to illuminate experimental work. Unfortunately, just as an artificial intelligence program ceases to be artificial intelligence and becomes instead computer science once it actually works, there is a tendency for successful theories in computational neuroscience to lose their visibility as they become smoothly integrated into the fabric of neuroscience. The highest accolade for ideas in science is, after all, to be taken for granted.

Several recent books have provided good summaries and reviews of computational neuroscience. These include *The Computational Brain* (P. S. Churchland and T. J. Sejnowski, 1992, Bradford Books/MIT Press), which gives a relatively gentle introduction to the area illustrated with mostly nonmathematical descriptions of some of the most influential models, and *The Handbook of Brain Theory and Neural Networks* (M. A. Arbib, ed., 1995, Bradford Books/MIT Press), a large-scale reference work consisting of short and pithy reviews of a comprehensive range of topics. In addition, a new textbook is currently in preparation by Abbott and Dayan that aims to provide a systematic and mathematically rigorous exposition of the subject. *Neural Organization: Structure, Function, and Dynamics* has a different aim from each of these: "to integrate structural, functional, and dynamical approaches to the interaction of brain models and neurobiological experiments" (quoted from the dust jacket). This is an ambitious goal, and the book falls slightly short of reaching it. However, there is much of interest to be found in the attempt.

The book's perspective is extremely broad, ranging from compartmental modeling to high level theories of cognition. Following chapters introducing the three subtopics mentioned in the title, the following specific neural systems are addressed in more detail: the olfactory system, hippocampus, thalamus, cerebral cortex, cerebellum, and basal ganglia. In each case, a number of basic themes dominate. The first of these is the modular architectonics principle, the idea that the structure of the nervous system is best characterized as made up of discrete segments. Examples discussed include the spinal cord, brain stem, and cerebral cortex. Another is schema theory, which is argued to be the most appropriate way to lay function on top of structure. Here, computational tasks are first defined and broken down without commitment to particular anatomical structures. The mapping between structure and function can then be made later, and the possibility retained for remapping as more data becomes available, or even for dynamic remapping during the normal operation of the nervous system. Multiple schemas may be simultaneously active and may both compete and cooperate to control behavior. Many examples of this framework are presented, particularly in the context of motor control, such as reaching and grasping.

A strong theme within the schema approach is that of action-oriented perception, the idea that perception is not simply a passive process of absorbing information about the world but is guided by particular goals for interacting with that world. An example of the overall approach is Arbib's work on Rana Computatrix, the

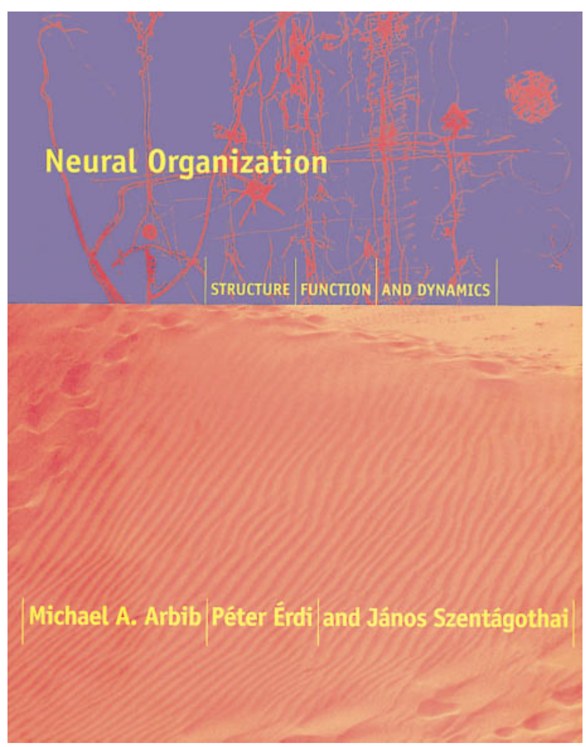

Figure 1. The Book Cover from *Neural Organization: Structure, Function, and Dynamics* Reprinted with Permission from MIT Press

computational frog. Arbib traces a path from the anatomy of the frog's visual system, through the computations that must be performed to convert visual inputs into appropriate actions, to the generation of behaviors such as prey capture and predator avoidance. Dynamics is analyzed from a fairly formal mathematical perspective and emphasizes two distinct levels. The first of these is the self-organization of patterns of neural activity, including a strong focus on oscillatory behavior. The second is the self-organization of patterns of synaptic connections. Here, the concern is mostly with activity-dependent learning rules that subserve memory storage and neural map formation, for instance the development of ocular dominance columns. Development also emerges as a theme in another part of the book, where the hypothesis is put forward that newly evolving structures tend to modulate rather than supplant the function of existing structures.

In a project of such scale, some minor criticisms are inevitable. The level of background knowledge taken for granted seems somewhat high in some parts given the multidisciplinary perspective, for instance of neuroanatomy in chapter 2 and mathematics in the chapter introducing the dynamical perspective. In addition, some sections are a little behind the times—for example, a discussion of cognitive neuroscience that hardly mentions fMRI and an analysis of retinotectal map formation that does not refer to the Eph receptor/ligand family. On a more general level, it would be impressive indeed to bind such a vast range of material into a coherent whole, and the book does not quite succeed at this task. Overall, however, it does provide a very useful resource for both modelers and experimentalists who wish to broaden their knowledge, and it offers insightful and challenging perspectives across a broad front. Each of the authors is scientifically well seasoned and brings with him many interesting philosophical and historical perspectives (sadly, Szentágothai died while the book was in preparation, at the age of 82). The book contains several good reviews of particular areas that are useful whether or not one buys into the authors' overall perspective. Multiple reiterations of the most important points provide helpful reminders of where the reader has been and where they are going.

Among other virtues, *Neural Organization* illustrates how theory now has a firm foothold in many areas of neuroscience, and how multiple levels of analysis can inform one another. The book certainly does not signal the obituary for brain modeling that at least one neuroscientist would apparently like to see—on the contrary, it documents the progress computational neuroscience has recently made and hints of the promise it holds for furthering our understanding of neural systems.

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