BOOKS: NEUROSCIENCE

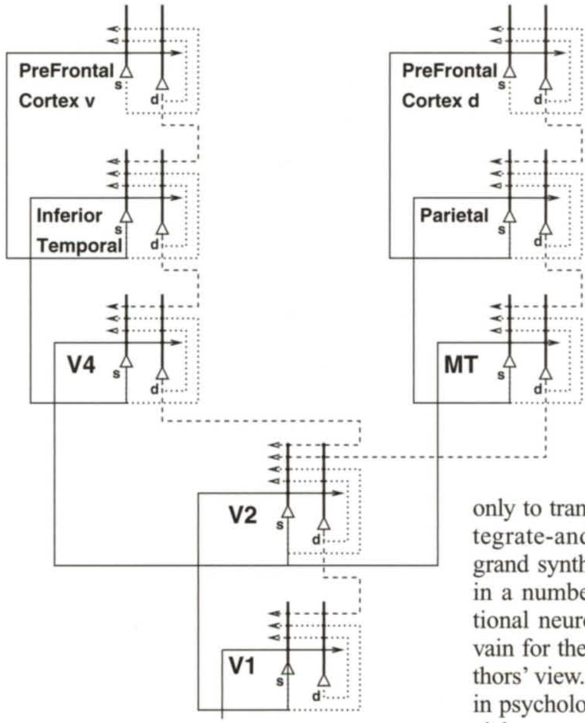
Networks for Seeing

Kevan A. C. Martin

The influence of theory in neuroscience has always been subtle. Not for neuroscience the many-world profligacy of physics or the other-world obscurity of mathematics, or even the all-encompassing world of Darwin's evolutionary biology. Instead, neuroscience has produced tiny islands of theory, archipelagos of mathematical models separated by vast oceans of data and speculation. Katz's quantal theory of synaptic transmission, Rall's application to neurons of Lord Kelvin's cable theory, and Hopfield's neural networks are some of the most prominent islands. In most neuroscientists' eyes, the pinnacle of theoretical neuroscience is Hodgkin and Huxley's model of the action potential, which they published 50 years ago. Their achievement was impressive both for the thoroughness of their experimental work and for the deceptive simplicity of their theory, captured in a single equation. Their model not only provided a comprehensive quantitative description of the action potential, it also set an example for the interplay of theory and experiment that remains unsurpassed, despite the intervening years of exponential growth in neuroscience.

Computational Neuroscience of Vision
by Edmund T. Rolls and Gustavo Deco
Oxford University Press, Oxford, 2002. 587 pp. $90, £50. ISBN 0-19-852489-7. Paper, $45, £24.95. ISBN 0-19-852488-9.

It is important to understand why Hodgkin and Huxley's model, arguably the first computational model in neuroscience, was so much more successful than anything that has followed. They were exceptional experimentalists who adapted and developed cutting edge technology. They came out of a system of science education where numeracy was highly regarded, and their knowledge of electronics and mathematics proved to be crucial. Their style of problem solving was also a key factor in their success. They chose an electronic metaphor for their model of the nerve cell membrane, and they were able to solve, on a hand-cranked mechanical calculator, the differential equations that described the time-varying membrane voltages they observed. Their approach was not to all tastes: some contemporaries referred to the theory as "the Hodgkin hallucination" (1). But what is now known as the HH model has lasted because it is couched in terms that are unashamedly electronic, placing the model in a secure position in relation to basic physics and in an unassailable position in terms of experimental testability.



An architecture for visual processing. In the authors' model, prefrontal cortical areas provide the short-term memory that holds active the object or spatial target of attention. Areas are connected by forward (solid) and back (dashed) projections. The triangles represent pyramidal cell bodies (superficial and deep), and the vertical lines above them, dendritic trees.

Most of the successful computational models in neuroscience concern single neurons, axons, and synapses. Yet it is also understood, implicitly and explicitly, that the cardinal property of nervous systems is that they are systems. Therefore, such determined concentration on single cells and synapses perhaps means that the majority of researchers in the field believe that if they understand enough about individual neurons and their function then, pari passu, they will have the insights they need into the computational properties of assemblies of neurons. A more banal view is that the continued focus on single neurons and synapses may simply reflect the inevitable bottleneck produced by the limited technical armamentarium of experimental neuroscience, because it is undeniably easier to study single neurons in vitro than an assembly of neurons operating in the brain of an animal as it carries out some behavior. These more philosophical speculations, however, have been largely blown away by the explosive growth of molecular neuroscience, which has presented a forceful argument for a purely "bottom-up" approach to understanding brain function.

In this post-genomic world, *Computational Neuroscience of Vision* is almost anachronistic. The book does not attempt to explain visual function in terms of the biophysical properties of neurons and synapses. It mentions the HH model only to transform it to the much simpler integrate-and-fire mechanism. It offers no grand synthesis, no unifying theory. Unlike in a number of recent books on computational neuroscience, the reader searches in vain for the neurobiological roots of the authors' view. Instead, its roots are to be found in psychology, computer modeling of artificial neuronal networks, information theory, and machine vision. The authors present experimental work including visual psychophysics, associative memory, attention studies, and microelectrode recordings from most of the brain regions known to have a connection, however indirect, to the eyes.

In its development of quantitative models, *Computational Neuroscience of Vision* is determinedly eclectic. The authors borrow freely from models of linear and nonlinear neural networks, mean field theories, and information theory as well as various psychological models of reward, neglect, learning, attention, and perception. This juxtaposition of many different levels and degrees of abstraction in theory with experimental psychophysics and neurophysiology is exciting because it offers, at the very least, visible points of contact among many different disciplines and lines of thought. The wind-blown curiosity of its senior author, psychologist Edmund Rolls, is strongly reflected in the book. The director of the Oxford Centre for Computational Neuroscience, Rolls has made significant contributions to both experimental and theoretical work on neural systems. He offers a level of exposition of experiment and models well suited to the book's potentially wide audience of advanced undergraduates and graduate stu-

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dents. His coauthor, Gustavo Deco, a physicist and computer scientist at Siemens, Munich, and the University of Munich, Germany, contributes the chapters on attention. Deco evidently takes a more optimistic view of the mathematical competence of his average reader, though the book does offer some assistance in two remedial appendices (on information theory and linear algebra for neural networks).

For Rolls and Deco, computational neuroscience is valuable because it provides a means of testing whether one has a correct theory. Computer simulations of a brain process lead, in their view, to "a precise definition of how the computation is performed, and to precise quantitative tests of the theories produced." In this regard, Hodgkin and Huxley's experience is worth recalling; they too followed this path, but their conclusion was rather different. At the end of ten years' work, they realized (to their great disappointment) that their electrophysiological data provided only very general information about the class of molecular mechanisms that might be involved in generating the action potential. So, as Hodgkin recalled, they "settled for the more pedestrian aim of finding a simple set of mathematical equations which might plausibly represent the movement of electrically charged gating particles" (*2*).

This paradox of knowing much yet not enough is one that besets all computational neuroscientists. It leads different authors to draw different borders between what they consider to be "biologically realistic" and "biologically inspired" models. Neural networks, which form the basis of most of the models in the book, clearly are highly abstracted versions of the biology, more inspired than realistic. But, as John J. Hopfield (himself a physicist) recognized, the value of his eponymous network lay not only in introducing a useful style of modeling into neurobiology but also in drawing quantitatively oriented scientists into the field. *Computational Neuroscience of Vision* provides encouraging indications that the field itself is spawning a new form of neurobiologist in which experimentalist and theorist share the same brain.

References

1. A. L. Hodgkin, *Chance and Design* (Cambridge Univ. Press, Cambridge, 1992).
2. A. L. Hodgkin *et al.*, *The Pursuit of Nature: Informal Essays on the History of Physiology* (Cambridge Univ. Press, Cambridge, 1977).

BOOKS: TECHNIQUES

Focusing on Truth and Beauty

Jake Miller

"The most beautiful thing we can experience is the mysterious," Albert Einstein once said (*1*). "It is the source of all true art and science." The difference between art and science is the way they approach the great mystery of truth. Art seeks to hold the mystery together in one inexplicable, irreducible whole, whereas science attempts to explain and understand the universe by examining it piece by piece.

Photographer Felice Frankel, a research scientist and artist in residence at the Massachusetts Institute of Technology's Edgerton Center, has spent the last decade harnessing her art in the service of science. Early in her career, she worked as a research assistant in molecular biology, and later she became a landscape and architectural photographer. As a Loeb Fellow at Harvard University in 1992, she began working on ways to combine her passion for science and her talent for image making. Since then, she has collaborated with researchers to produce stunning photographs of the results of scientific experiments and engineering demonstrations, images that use vivid colors, energetic compositions, and carefully designed samples to convey, as clearly as possible, the main ideas of her collaborators' work.

Envisioning Science
The Design and Craft of the Science Image
by Felice Frankel

MIT Press, Cambridge, MA, 2002. 336 pp. $55, £37.95. ISBN 0-262-06225-9.

Frankel's *On the Surface of Things* (*2*) featured her photographs of subjects like ferrofluid and migrating bacteria along with chemist George M. Whitesides's poetic explanations of the scientific phenomena pictured. Last year, she helped organize a conference that brought together scientists, journalists, and imaging experts to discuss new approaches to scientific imaging. Her latest book, *Envisioning Science: The Design and Craft of the Science Image*, is a how-to manual intended to show students and researchers ways to use the aesthetic powers of photography to better communicate their scientific findings to their scientific colleagues and to people outside their research communities.

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BROWSINGS

Vision and Art. **The Biology of Seeing.** *Margaret Livingstone.* Abrams, New York, 2002. 208 pp. $45, C$65, £29.95. ISBN 0-8109-0406-3.

What goes on in our brains when we look at a work of art? Livingstone, a neurophysiologist, offers an account that will help readers appreciate both the science and the art. After reviewing the biology of vision, she explores how various images reflect particular aspects of our visual system. To consider the different roles played by color and luminance ("perceived lightness," what artists call value), she presents color and black-and-white versions of many paintings. Ben Shahn's *Triple Dip* (left) demonstrates that colors having a low-luminance contrast with the background will seem to conform to high-contrast outlines even when they do not.

Measuring Mass. From Positive Rays to Proteins. *Michael A. Grayson, Ed.* Chemical Heritage Press, Philadelphia, PA, 2002. 159 pp. $35. ISBN 0-941901-31-9.

The first mass spectrographs were used to separate the elements on the basis of their mass, but the approach was soon extended to the analysis of chemical compounds. Written for lay readers as well as practitioners, the short, profusely illustrated essays in this volume sketch the history of the tool and survey the diverse uses it has been put to in fields ranging from geology to forensics.

Chips Challenging Champions. Games, Computers and Artificial Intelligence. *Jonathan Schaeffer and Jaap van den Herik, Eds.* Elsevier, Amsterdam, 2002. 370 pp. $40, €40. ISBN 0-444-50949-6.

The development of programs that play classic games has played an important role in artificial intelligence research.