Molecules and the Mind

Information in the Brain. A Molecular Perspective. IRA B. BLACK. MIT Press, Cambridge, MA, 1991. xxii, 225 pp., illus. $30. A Bradford Book.

The culmination in the 1950s of many years' effort to discover the basis of heredity will long be regarded as a watershed in biological research. On a more immediate time scale, however, the molecular biological revolution has also had some less fortunate consequences. Preeminent among these is the common belief that explanations of biological phenomena not offered at the molecular level are of little value. Nowhere is this problem more evident than in neurobiology. The issues outstanding in this complex field range from unequivocally molecular questions—the genetics of neuronal differentiation or the mechanism of ion selectivity in membrane channels, for example—to quasi-philosophical concerns, such as the basis of consciousness and the nature of perception. Despite this diversity, there is a widespread conviction that neurobiological problems—from membranes to mind—must be solved primarily in molecular terms. This book is important because it requires the reader to confront squarely the question of whether the present enthusiasm for molecular explanations of the brain—in all its manifestations—is well founded.

Black's aim is an ambitious one, motivated by a perceived "crisis" arising from the absence of a "mechanistic vocabulary" that might animate a general theory relating "mind, brain, and behavior." The stated goal of the book is "to utilize a series of new and radical insights derived from neuroscience to develop a novel formulation of the physical basis of brain function and mind" (p. xii). An excellent expositor, Black is at his best when describing the neurotransmitters associated with particular brain systems and the functional roles such molecules are known to play. The middle chapters, which form about one-third of the book, are largely built upon information now available about catecholaminergic subsystems, the mechanism of catecholamine action, and the regulation of these transmitter molecules and their synthesizing enzymes. This work, to which Black has made important contributions, provides a compelling argument for the proposition that a great deal of useful knowledge about signaling molecules has been gleaned that can sometimes be correlated with behavioral effects. Lucid reviews of trophic factors, opiate peptides, and various molecular dysfunctions that lead to neurological disease are also presented.

Less successful is Black's attempt to place these often fascinating phenomena in a general framework in which molecules serve as "symbols" that link the nuts and bolts of brain function to such fashionable issues as cognition, self, and mind. The central idea he proposes is that neurotransmitters and other signaling molecules in the nervous system have multiple functions. From this generally accepted fact (which applies to hormones and other molecules that convey biological signals), Black extracts a "principle of polyfunction" that is meant to endow neural signaling molecules with special significance. The symbolic role that Black attributes to neurotransmitters derives from their ability to provide an internal representation of external circumstances. The internal symbols arising from the actions of transmitters and other neural signaling molecules constitute a "representational structure that participates in the ongoing operation of the system itself." Summarizing the relation between symbol, self, and subjectivity, Black concludes that "the continuous cycle, the continuous interaction of multiple levels, continually changes the self and its cognitive and emotional underpinnings. . . . Levels within levels and cycles within cycles interact to form and mold the self. . . . It may be concluded that multidirectional interactions among levels are fundamental to brain function and that higher-level regulation of lower-level symbols is widespread throughout the neuraxis. . . . The self, then, is a vast aggregate of functions distributed throughout the brain and even the entire neuraxis" (p. 179). The meaning of all this may be a good deal less clear to readers than his exposition of the conventional roles of transmitters and other molecules that affect neural signaling.

The difficulties Black encounters are largely the result of his persistent attempt to subsume a diversity of poorly understood brain functions under a general theory about molecular signaling. This single-mindedness, while admirable, leads to forced and sometimes inchoate arguments. Understanding any complex phenomenon—a work of art, for instance—demands a variety of intellectual (and technical) schemes. Most art enthusiasts would seek to fathom a painting in terms of form, content, esthetic canons, the social setting of the artist, and so on. Few would wish to limit themselves to analyzing the composition and chemistry of the paint or to elaborate a theory of art on such a limited basis. The molecular framework that Black chooses for this book *does* beautifully illuminate a number of the neurobiological issues he raises. Others such as the nature of subjectivity, self, cognition, and mentation are not much informed by this line of attack.

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Visual Systems

Development of the Visual System. DOMINIC MAN-KIT LAM and CARLA J. SCHATZ, Eds. MIT Press, Cambridge, MA, 1991. xii, 299 pp., illus. $65. Proceedings of the Retina Research Foundation Symposia, vol. 3. A Bradford Book. From a symposium, Woodlands, TX, May 1990.

The highlight of this book is its first chapter: a sparkling account of retinal development in *Drosophila* by Seymour Benzer. Throwing a formidable battery of genetic, molecular-biological, and neuroanatomical techniques at the problem, Benzer and other workers have demonstrated the importance of intercellular communication and regulation, as opposed to cell-autonomous development, in bringing the fly's photoreceptor cells into their crystalline arrays. They have also defined a set of genes that are expressed in a hierarchical sequence during retinal development and whose role, in some cases at least, is understood at a biochemical level. Benzer stresses the potential for application of these findings to an understanding of the development and maldevelopment of the human eye and brain; the radical differences in structure conceal, in his view, a vast shared genetic heritage that current technology makes ripe for analysis. Only at one point does his enthusiasm carry him away, when he states that studying the fly's eye convinced Cajal of the existence of God. Actually that lifelong agnostic only remarked that it "weakened his faith in Darwinism"—a more modest lapse to which Darwin himself was occasionally prone.

Genes get scant attention in the rest of the book, most of whose contributors are neuroanatomists and physiologists. Even so, one can't help being impressed by the ingenuity of current experimental techniques, which include lineage analysis with retroviral vectors (Altshuler, Turner, and Cepko), observation of growing axons *in vivo* (Fraser; Holt; Stuermer), NMDA-receptor blockade (Cline; Daw and Fox), and various types of transplants, reroutings, or selective ablations (Reh; Harris; Fraser; Shatz *et al.*; Sur). Development plasticity in the ocular dominance system, first described by Hubel and Wiesel almost 30 years ago, is still a hot topic—the attention has largely shifted from the physiology and anatomy to an analysis of the synaptic mechanisms involved (Daw and Fox; Cynader *et al.*; Stryker). Michael Stryker even throws in for good measure a (nondevelopmental) explanation for that other Hubel and Wiesel conundrum, orientation tuning.

The main message that seems to be emerging from this work is that, even more than in the fly's eye, the vertebrate visual system depends for its development on interactions between cells, regulation, and plasticity, rather than rigid cell-autonomous programming. The role of the "subplate"—a small, transient population of neurons that sits under the developing visual cortex and that seems to influence the formation of the permanent connections of the cortex—is an especially interesting example of this (Shatz *et al.*). Indeed, this kind of interactive development seems the only conceivable way to go if one has to put together a brain vastly larger than a fly's with a genome that is only modestly expanded. These interactions are probably mediated by a fairly small box of molecular tricks that are used over and over again: diffusible and cell-surface markers, receptors, second messengers, transcription factors, and so on. The trick that seems closest to being pinned down is the NMDA receptor and its potential role in the generation of activity-dependent patterns of connectivity. As to the mechanisms that operate earlier to convert multipotential postmitotic cells into the highly specialized neuron types of the mature visual system, this book gives some idea of their general character, but their actual identity remains obscure. Let us hope that Benzer is right.

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Special Kinds of Knowledge

What Engineers Know and How They Know It. Analytical Studies from Aeronautical History. WALTER G. VINCENTI. Johns Hopkins University Press, Baltimore, MD, 1990. viii, 326 pp., illus. $45. Johns Hopkins Studies in the History of Technology.

Over the years there has been a widespread belief, especially among some scientists, that modern engineering is a subdiscipline of science that does nothing more than apply the results and discoveries generated by pure science without making any fundamental contributions to those discoveries. Recently many scholars, particularly historians of technology, have come to challenge this belief. They argue that engineering generates its own form of knowledge in the form of concepts and methodologies that cannot be simply reduced to scientific knowledge. As Herbert Simon has observed, science deals with how things are whereas engineering deals with how things ought to be. This difference is reflected in the fact that engineering knowledge, unlike scientific knowledge, is not about the natural world but about humanly designed objects such as structures and machines.

In this book, Walter G. Vincenti draws on his background as both an aeronautical engineer and a historian of technology to investigate the nature of engineering knowledge. Through five case studies in aeronautical engineering, he examines how problems arising from normal design requirements have complex epistemological consequences that distinguish engineering knowledge from applied science.

The study of Consolidated Aircraft's decision during the 1930s to use David R. Davis's unconventional airfoil design for its B-24 shows how engineering design grows in the face of incomplete and uncertain information. Empirical tests done with small-scale models at the wind tunnel at the California Institute of Technology indicated that the Davis wing had superior characteristics compared with more established designs, but engineers were unsure how such tests would relate to actual performance. This uncertainty was compounded by Davis's inability to provide an acceptable theoretical basis for his airfoil design. Vincenti argues that attempts to decrease such uncertainties through a complex interaction between theory and experiment became a significant factor in the growth of engineering knowledge.

Vincenti's discussion of early aircraft design illustrates how design requirements grew out of a conflict between the preference of one group of engineers for a plane that had inherent stability and another group's preference for a plane that had a high degree of maneuverability. In this case the subjective needs of pilots helped to shape the debate. The eventual conclusion that airplanes should be stable but not too stable represents how an entire community of engineers and pilots played a role in the generation of engineering knowledge.

A study of control-volume analysis provides an example of how a subject is approached differently by engineers and scientists. Engineering textbooks treat problems in fluid mechanics and thermodynamics in terms of an imaginary control volume or control surface, but such concepts are absent in physics textbooks. Vincenti argues that the mathematical formalism of control-volume analysis arose from the demands of design and the economic constraints that faced engineers. They must design artifacts, and control-volume analysis lends itself better to a concern for overall results. Scientists, on the other hand, are concerned with understanding the workings of nature and usually need a detailed point-by-point description of phenomena.

A discussion of the aircraft propeller tests conducted by W. F. Durand and E. P. Lesley from 1916 to 1926 shows how engineers acquire the quantitative experimental data they need to carry out design. Through a process of parameter variation, Durand and Lesley conducted wind-tunnel tests on a large number of propellers. Vincenti argues that such testing represents an important methodology used by engineers that differs from the experimental method used in science. Experimental parameter variation could provide design data needed by engineers when they were faced with the lack of a useful quantitative theory.

The development of the techniques of flush riveting in the American airplane industry between 1930 and 1950 provides an example of engineering knowledge that did not involve any dependence on science. Rather, flush riveting reveals a different kind of technological knowledge that could be called prescriptive knowledge, or knowledge of procedures and operations. This type of knowledge differs from descriptive knowledge, or knowledge of facts, which is more closely associated with science.

These examples provide the basis for a model of engineering knowledge. Vincenti identifies the knowledge-generating activities in engineering as theoretical tools and data transferred from science, invention, theoretical engineering research, experimental engineering research, design practice, production, and direct trials. He concludes by exploring the idea that such knowledge grows by way of a blind-variation–and–selective-retention model put forward by the