variable." (Such combinations of boldface type and italics occur frequently.) A beautiful example of adaptive control is a man catching a ball. If the ball were suddenly perceived to be "a concrete block or a live rattlesnake," then "the standard of operation [would have] to be switched from wanting-to-catch to not-wanting-to-catch." It is precisely at this point that Reiner might well have added a footnote to say that he has no explanation for the undoubted fact that all too frequently the human adaptive control system will inexplicably switch back to wanting-to-catch the tossed rattlesnake.

The background of the author does much to explain his approach to life processes. His early interests involved enzyme kinetics, and he is the author of a useful manual entitled *Behavior of Enzyme Systems* (Burgess, Minneapolis, 1959) and numerous chapters in books edited by others, all of which are modestly omitted from the index though listed among references on page 134.

It would be impossible to catalog the contents of this remarkable book here since it goes so far in its attempt to integrate modern feedback concepts with molecular biology and with ideas about the organism as a whole, and it would be nit-picking to attack specific details of fact or omission. One can only be tolerant of an occasional cavalier pearl of wisdom such as the footnote "An interesting speculation to consider is the possibility that cancer may result from an accidental failure in the supply of certain repressors in an occasional cell. It is questionable, however, that this could be a universal mechanism . . ." (p. 193). As if the literature on this possibility were nonexistent.

But it is precisely the converse of this example that illustrates one of the book's greatest virtues. Absence of citations would not be remarked were it not for their presence throughout the book, which is divided into six major sections including discussions of the genetic control mechanisms, classical genetics, multienzyme systems, and the organism as a whole. Each section has its own reference list ranging from 11 or 18 references in the shortest sections to 80 or 90, even 164 in the longest. The author could not possibly include all of the relevant literature or even the most important literature. He does manage to do what seems to me the obligation of every writer of a book of this kind, to refer to the literature that moved *him*. At least the reader can then compare the author's sources with his own and make allowances for differences in outlook, and if he has no references of his own he will have a beginning.

The most curious lapse in the entire book is the final sentence. In the preface we are told that someone should try to say "what it is all adding up to." At the end, "finding relations in the universe . . . is not solely a luxury to be tossed contemptuously to the philosophers . . . . It is what distinguishes the scientist from . . . the technician with a Ph.D. and a fistful of government grants." So far, so good, if that's the way he wants to put it. But then the final sentence: "But even when seen as a form of self-indulgence, the capacity to discern, however nebulously, a logical route from enzymes to man and society can be recommended as an intoxicant devoid of side effects." No side effects, that is, until adaptive control systems begin to ask embarrassing questions about why they do what they do.

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Learning, Perception, and the Brain

Integrative Activity of the Brain. An Interdisciplinary Approach. JERZY KONORSKI. University of Chicago Press, Chicago, 1967. xii + 531 pp., illus. $15.

The mind boggles at the gap between the richness of human consciousness and its basis in the movement of ions measured in microns and milliseconds. We are beginning to see, if only dimly, how ionic movement may give rise to action potentials, neuron firing to sensory coding, sensory information to perceptions to memory and thought; yet the difficulty of relating molecular and mental events remains enormous. *Integrative Activity of the Brain* is a bold attempt to cross this chasm and integrate the concepts of modern neurophysiology with the phenomena of learning and perception.

After a half century of contributions to the study of learning and brain function, Konorski is uniquely prepared for this task. It was, for example, Konorski and his colleague S. Miller who first distinguished experimentally between the two types of learning that are now the main concern of American learning theorists. In the 1920's, in Pavlov's laboratory, they first described "Type II" conditioning (the more common American terms are operant or instrumental learning) to distinguish it from "Type I" conditioning, which Pavlov discovered (Pavlovian, classical, or respondent conditioning). The textbook example of Type I is a dog salivating to a bell previously paired with food, and of Type II is a rat pressing a lever for food.

Since then, Konorski has studied in detail the relations between these two types of learning, unlike most students of learning, who tend to focus entirely on one or the other. His previous book in English, *Conditioned Reflexes and Neuron Organization* (Cambridge University Press, Cambridge, 1948), describes many of these early studies and, in addition, contains a detailed critique of Pavlov's theory of learning based largely on data from Pavlov's own laboratory. In recent years, Konorski and his colleagues in the large and active Department of Neurophysiology at the Nencki Institute in Warsaw have carried out a broad program of experiments on problems ranging from avoidance conditioning and the role of proprioception in learning to aphasia and the functions of specific brain structures in behavior. The present book, although not intended as a review of these studies, does summarize many of them *en passant*.

Konorski presents a plausible account of the physiological basis of behavior, drawing chiefly on three sources of inspiration: contemporary neurophysiology, learning experiments carried out in his laboratory, and—somewhat unconventionally—his own introspections. Hebb has said that psychological theory is usually based implicitly on long-out-of-date physiology; Konorski's physiology is at least contemporary and sometimes futuristic. Among the physiological concepts that mold his theory are centrifugal control of sensory input, hierarchical processing of information in sensory systems, lateral inhibition, the control of motivation by excitatory and inhibitory hypothalamic centers, and facilitation of cortical activity by the reticular formation.

Central to Konorski's theorizing is his view of neural organization in perception, which derives from Hubel and Wiesel's demonstration of hierarchical processing and coding of information in the visual system. First Konorski extrapolates this schema to the other sensory systems. Then, on top of the sensory hierarchies, he builds an analogous hierarchy forming the basis of cognition and learning. The theory assumes that at each level of every sensory system some neurons have a "receptive" function ("transit units") and some have a "perceptive" function ("exit units").

The transit units communicate with higher-level units in the same sensory system. The lower-order exit units may give rise, *inter alia,* to "targeting" or "orientation" reflexes, reflexes controlling sensory input, and reflexes to noxious stimuli. The higher-order exit units are "gnostic units"; they form the anatomical substrate of cognition and association. Unlike connections among transit units, connections involving gnostic units seem to be only potential at birth and are made actual when the gnostic units simultaneously receive input from the "arousal" system and from transit units. This arousal seems to be somewhat specific, since it derives from the animal's orientation to the stimulus activating the receptive units or from specific "drive centers." Gnostic units become connected with one another in a hierarchical fashion. The activation of gnostic units gives rise to "unitary" perceptions. Gnostic units are arranged in gnostic fields, identified roughly with regions of association cortex. Destruction of a gnostic field produces a specific agnosia. On the basis chiefly of human neuropathology and his own introspections, Konorski provides a catalog of gnostic fields (such as spatial relations, manipulatable objects, melodies) and diagrams of the principal associations (potential connections) among them. Emotion has its gnostic field, too, and gnostic units in it may form connections with gnostic units in other gnostic fields. The gnostic field for emotion is roughly identified with the limbic system and receives its inputs both from other sensory systems and from the drive centers in the hypothalamus.

Konorski's treatment of the kinesthetic system is perhaps the most original and interesting aspect of his theorizing about perception. Receptors in the muscles deliver their messages to the cerebellum, where they are "translated from the language of tensions into the language of movements." Thus, the cerebellum is the "kinesthetic receptive surface." The cerebellum sends its output to precentral cortex (which is viewed as the projective area of the kinesthetic system just as postcentral cortex is the projective area of the somatosensory system). Precentral cortex then sends messages to the kinesthetic gnostic field, which is identified with premotor cortex. The kinesthetic gnostic field is somewhat different from other gnostic fields because it has direct connections with cortical motor mechanisms and it is supposed to act as their "programming device." Although the kinesthetic gnostic fields need information from the muscles for their development, once formed they are relatively independent of sensory feedback. This scheme deemphasizes the role of peripheral feedback in movement and is supported by dramatic experiments by Konorski and others which show considerable motor ability after radical deafferentation.

In Konorski's theory, both Type I (Pavlovian) and Type II (instrumental or operant) conditioning are special cases of association between gnostic fields. Classical conditioning involves association between two gnostic units (representing the conditioned and unconditioned stimuli), one of which, when activated, produces an unconditioned reflex. As with other associations, this association must be facilitated by an arousal input. In this case, the arousal arises from hunger, fear, or some other drive center. Thus, in Konorski's view of Pavlovian conditioning, unlike that of most American theorists, drive plays a central role. In instrumental conditioning, the association is between units in the gnostic field for emotion which are activated by a specific drive and kinesthetic gnostic units that control a particular motor response. In addition to this specific role, drive is again believed to provide the arousal required to establish the association.

Although this synopsis is necessarily brief and incomplete, it may convey something of the flavor of Konorski's theorizing. His English is better written and more pleasurable to read and think about than an equivalent number of pages of American journal articles on learning, perception, or physiology. His introspections are often very different from mine, but they certainly enliven the text.

Konorski's theory is open to criticism on many specific counts. The physiology is often oversimplified and usually consists of loose extrapolation rather than demonstrated mechanism. The principles of learning occasionally conflict with recent findings (as for example his claim that errorless learning is impossible). Yet such criticism is rather picayune and irrelevant given the broad aim of the book. In spite of the scarcity of data available today, Konorski has formulated an intriguing account of how the brain is likely to work. It cannot help stimulating its readers, and it will certainly send many of them into the laboratory with new ideas or at least with a better conception of how their little experiments might fit into a larger scheme of things. Konorski's theorizing is unlikely to convert many operationally minded behaviorists who think that physiology is irrelevant to the study of learning and that elaborate diagrams of hypothetical centers and connections to "explain learning" are worthless. However, I particularly urge them to examine the chapters on learning, which constitute more than half the book. They contain many interesting and original experiments that demonstrate the heuristic value of elaborate theorizing.

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Boveri

Theodor Boveri. Life and Work of a Great Biologist, 1862–1915. FRITZ BALTZER. Translated from the German by Dorothea Rudnick. University of California Press, Berkeley, 1967. xviii + 165 pp., illus. $6.

Science published a review of the original German edition of this book [by Viktor Hamburger, **136**, 709 (1962)] and, later, a translation of a lecture on Boveri given by its author [**144**, 809 (1964)]. The latter is a tantalizing introduction to topics covered more exten-