Rosen's goals are to show that optimality is a powerful central concept that can be used to demonstrate underlying relationships between apparently diverse problems and phenomena in mathematics, physics, biology, and the social sciences; to point out some of the important problems; to describe some of the mathematical tools; and to encourage the reader to formulate and solve such problems. To achieve these ends, his book relates a surprisingly diverse group of topics, including the calculus of variations, structure of the vascular system, ontogeny and phylogeny, allometry, homeostasis, feedback systems, pattern recognition and the perceptron, organisms, and societies. The discussion of feedback systems is particularly rigorous and penetrating and will lead biologists to new insights as a result of its emphasis on the distinction between feedback through the parameters (alternation or evolution of system design) and feedback by modification of input data. This distinction is useful, since in many cases both mechanisms operate. A great merit of this book is its repeated linking of analogous problems in different fields; for example, programming problems in economics and the behavior of entrepreneurs are shown to be similar to those of general adaptive systems seeking to avoid negative reinforcements from the environment.

Perhaps the most powerful idea in this book is that of using optimality techniques to discover what is being selected for in evolution. For example, we might ask the question, what determines the radius of the aorta? To answer this, various hypotheses are formulated as to what variable is being maximized or minimized. Mathematical manipulations yield the optimal aorta radius given each of the competing hypotheses. By comparing the actual radius of the aorta with the optimal radii for the various hypotheses we can see which variable selection has most likely been operating on. Thus, if selection has been such as to minimize the power dissipated through blood flow, the human aortic radius would be approximately 0.4 centimeter. If, on the other hand, selection has been such as to ensure laminar rather than turbulent flow through the aorta, the aortic radius would be equal to or greater than 1.3 centimeters. Since the human aortic radius is about 1.5 centimeters, avoidance of turbulent flow appears to be a more realistic hypothesis for the object of selection. This working method can be elaborated considerably with respect to the complexity of the data to be analyzed and the analytic procedures used and can thus yield profound new insights.

This reviewer has found that the book, in addition to providing provocative reading for mature researchers and graduate students, can be used as a text for part of the lectures in a biomathematics course for seniors and graduate students whose only mathematical preparation is two courses in calculus and three in statistics. Enough discussion of more advanced mathematics is given so that the text is self-contained. In summary, the book is highly recommended for biomathematicians and students in this burgeoning field.

KENNETH E. F. WATT
Department of Zoology,
University of California, Davis

What Is a Living Organism?

The Organism as an Adaptive Control System. JOHN M. REINER. Prentice-Hall, Englewood Cliffs, N.J., 1968. xii + 224 pp., illus. $6.75.

The title of this book is noteworthy in itself. As the author points out, the past two decades have seen great advances in our understanding of molecular mechanisms of control or regulation. What the book is really about is "The Organism as a System of Environmentally Modifiable Physicochemical Regulatory Devices," and Reiner has achieved a simplification of this by borrowing from the title of Richard Bellman's book *Adaptive Control Processes.* The book is indeed timely, since it comes as a refreshing antidote to the type of arguments recently presented to the AAAS in a panel discussion entitled "Do Life Processes Transcend Physics and Chemistry?" and now available to an unsuspecting public in the form of 2½ hours of video tape [see *Science* **159**, 760 (1968)]. Reiner's answer to this question is not ambiguous, and if given equal time he could do much to dispel the idea that reductionism and holism are antithetical.

Reiner's historical introduction makes it clear where he stands: Berthollet (1803), Liebig (1878), and Loeb (1924) are quoted, always in support of the antivitalist theme. Mathematics is the discipline that Reiner insists upon, and his occasionally flippant style suggests a rather noncharitable attitude to those who ignore it. He insists that mathematics is only incidentally the science of number. Rather, it is a formal, symbolic, exact way of representing properties and relations of any sort, and is thus preeminently the science of structure and pattern. Unfortunately this message was not conveyed by the "refugees from Phys Ed and the grocery-store cash register who . . . taught most of us . . . ." So if scientific biology is biology *cum* mathematics, what is meant by unscientific biology? Reiner answers in his picturesque way that it is the kind "that collects observations—or even quantitative measurements—the way a bum collects cigarette butts."

Reiner is no amateur in mathematics: he reads Nicolas Rashevsky, who is obviously his archetype, referred to 23 times according to the index. François Jacob is runner-up with only six citations.

The interest of the book does not derive from the asides therein, which many will do well to ignore. Its merit lies in its clear exposition of what it is about, and it should be the personal property of every scientist and every amateur who has more than a casual interest in life processes from any point of view.

On a previous occasion I suggested that the question is no longer whether man is a machine but rather what kind of machine is man. Reiner answers the question better than it has been answered in any other volume known to this reviewer, although he tends to imply that adaptive control systems are free from irrational responses [compare *Science* **146**, 1018 (1964)]. There is much to be said for Reiner's approach, and the use of the word "machine" even with qualifications is probably needlessly diversionary. Instead we need to learn what is meant by the term "adaptive control system," because that is what a living organism is, and no doubt about it. On pages 30–31 Reiner's exposition is simplistic but didactically excellent. "In an uncontrolled system, the **mode of operation** is *invariable* (e.g., a stamping mill, a conveyor belt, an electric clock). In a controlled system, the **mode of operation** is *variable*; what is *fixed* is a **standard of operation**, a criterion according to which the control device varies the operation of the effector. In an adaptive control device, the **standard of operation** would be *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.

VAN RENSSELAER POTTER
McArdle Laboratory,
University of Wisconsin
Medical School, Madison

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 uncon-