as Koestler does, is a grotesque exaggeration. The vast bulk of modern academic psychology—even at Harvard and even at Yale—is far and away and beyond the ken and concerns of Skinner and Hull. I am not here arguing that Koestler is flogging a dead horse. I quite agree with him that behaviorism is not a dead nag, that its neighings and its whinnyings are still heard in the land; but I am asserting (and in the process am doing violence to a metaphor) that by far the largest part of psychology is a horse of quite a different color, indeed of many splendid different colors. Koestler tells us that he is seeking, in this book, to make a contribution toward a "true science of life." That is a most noble purpose. But why then neglect almost all of psychology? Why neglect such areas as psycholinguistics, personality research, brain and behavior research, the modern and very much refurbished research in verbal learning, cognitive psychology, social psychology —all of which are taught at the great majority of our contemporary universities and almost none of which has even distant kinship with behaviorism?

And so we both stand at fault. Those chapters which we will find less than delightful will be chapters in which Koestler has found us out in our foolishness, but in which he attacks us unfairly and with something less than the scholarliness we might expect from him. I strongly suspect that the geneticist and the evolutionist would testify similarly regarding Koestler's treatment of their sciences.

Koestler's book, for a psychologist at least, has other failings. After demolishing the cracked pillars of our unwisdom, he turns to construction. And here he has much to say. But many of the true things he has to say—about behaviorism (in a chapter titled "The poverty of psychology"), about the mind-body relation (in the chapter from whose title he has taken the name for his book), about the problem of units of analysis in science (where he coins a most useful word, "holon," to substitute for a number of words originally employed by the Gestaltists), or about neurological theories of emotion (The Three Brains)—have been said too often to sound new, even on Koestler's clever tongue. Many of the new things he has to say—especially about the cause and cure of the self-destructive tendencies in man—seem just too simple to be true, even with his long (300 pages) buildup and preparation for the denouement. The ability to integrate our emotional urges with our intellectual ones—the lack of which today threatens our very survival—will come, he believes, only when biochemistry discovers the Pill which will bring about a "state of dynamic equilibrium in which thought and emotion are re-united, and hierarchic order is restored." I miss (and am surprised to have to say this of Koestler) a more sophisticated discussion of the political, economic, psychological, and sociological supports which would be necessary if his Pill is to solve modern man's predicament. As his conclusion now stands one might (and no doubt many will) accuse Koestler of having written a book of science with a science-fiction ending in which a naive Better-Living-Through-Chemistry doctrine is presented as a solution to all our international ills.

And yet, as I reread the last few paragraphs which I have just written, I feel that I have done Koestler's book an injustice. His book is better than I make it sound. And I think I know the reason why. It is because I have reviewed the book Koestler thought he had written, rather than the book I enjoyed reading. Koestler believes that in his examination of psychology and genetics and evolution and the brain sciences he was picking up the "loose ends, the threads of ideas trailing in the fringes of orthodoxy . . . to weave them into a comprehensive pattern in a unified frame." If this was Koestler's objective, then I must judge his effort a failure. There are too many lacunae, too many solutions on too abstract a level, too much selection of data-to-fit to call this a "unified frame" for serious scientific theorizing, speculation, and research. I cannot agree with the blurb on the book's jacket (for which, of course, I do not hold Koestler responsible) that Koestler's thesis "is certain to provoke controversy and debate for years to come."

But if we read Koestler's book not for what he thought he was writing, but for what valuables we can find in it, then I can wax much more enthusiastic about it. I am tempted to say that Koestler has written a good book despite himself. For we have here a collection of lucidly written and compelling critical and speculative essays on the many-faceted life sciences. Of how many books can it be said that no chapter bores? Even the irritating chapters and even those with the oft-told tales provoke thought and, at the end, have profited the reader. And of how many books can it be said that again and again the reader is forced to stop and puzzle and speculate about matters which he had thought already to have been settled to his satisfaction long, long ago? (Reread the four "monumental superstitions" quoted at the beginning of this review.) Koestler has written a frequently unsettling and, therefore, a lively and interesting book which the scientist can read with profit, but above all—and that is so rare—with pleasure.

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The Biological Uses of a Venerable Concept

Optimality Principles in Biology. ROBERT ROSEN. Plenum, New York; Butterworths, London, 1967. xii + 198 pp., illus. $9.75.

The concept of optimality has become familiar to most scientists, largely because of its central importance in operations research, or systems analysis. In this context, one seeks to maximize or minimize one or more dependent variables through appropriate selection of variate values for independent variables. Because of the great importance of this problem in many areas of science, a formidable body of mathematical techniques has been developed for dealing with it. As Rosen points out, optimality also has a venerable history in physics, as for example in Fermat's principle of least time, Maupertuis's principle of least action, and Hamilton's principle. Since the most powerful central concept in biology, evolution through the survival of the fittest, is in effect an optimality principle, it is surprising that a comprehensive effort to apply optimality to biology has awaited the arrival of this interesting little book. Rosen has made such an effort, and if the ideas he presents are extended and applied with sufficient ingenuity, some of the ultimate consequences may be very important indeed.

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.

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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