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Computers and the Life Sciences

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Any writing on computers faces the hazard of instant obsolescence. The "second generation" computer is now a rapidly aging six-year old. In the time needed to obtain some perspective and win even a glimpse of consensus on the career prospects of this youngster, he is already a technological misfit. "7090" could evoke pure awe from the freshman, serve as a grudging partner of the sophomore and a workhorse to the junior, and then graduate as an antique like the model-T or the DC-7. Professors and monographers are less flexible and more sentimental than their students, for they find it harder to shed the milieu of their own indoctrination. However, we certainly need their books and monographs even if the gestation time conforms more closely to human than to computer-mechanical time scales. Four recently published treatises are reviewed here—**Use of Computers in Biology and Medicine** (McGraw-Hill, New York, 1965. 989 pp., $29.50), by Robert S. Ledley; **Computers and the Life Sciences** (Columbia University Press, New York, 1965. 352 pp. $12.50), by Theodor D. Sterling and Seymour V. Pollack; **Computers in Biomedical Research**, vols. 1 and 2 (Academic Press, New York, 1965; vol. 1, 584 pp., $20; vol. 2, 363 pp., $14), edited by Ralph W. Stacy and Bruce Waxman; and **Mathematics and Computer Science in Biology and Medicine** (Her Majesty's Stationery Office, London, 1965. 327 pp. £3), edited by Harold Himsworth and George Godber.

Use of Computers in Biology and Medicine and *Computers in the Life Sciences* are didactic efforts which should benefit from unity of authorship. That advantage is possibly outweighed by their inevitably longer gestational delay and their preoccupation with an implicit hardware set that has diminishing relevance. This is a special difficulty in Ledley's volume, most of which must have been written at least 5 years ago. In fact, the potentially most interesting sections have lost more than they have gained in their revision from his previous works. His predilection for a three-address machine may have some design basis, but is increasingly at odds with the actual trends in the field. The same engineering bias is apparent in the rather confusing and inefficient treatment of the programming languages which are the mainstream of computer science. It will be enough to note that "FORTRAN," "list-processing," and "assembly language" are absent from the index and to quote from page 83: "The fewer addresses that appear in the instruction format, the more complicated the coding becomes and the greater the number of instructions required in a code. Thus automatic-programming aids become especially important in one-address instruction formats."

As much as I admire Ledley's exposition of hardware design, I must deplore this approach to teaching about computers, even for teaching engineers, and much more as an approach for teaching the use of computers for research applications. A large part of his book is a textbook for an undergraduate course in mathematical analysis. This is not directly related to computation, but may reflect the mathematical sophistication needed for analog computation and for some of the simulations of biological systems which make up the rest of the work. On the other hand, there are many valuable nuggets strewn over the landscape, and for these nuggets alone I would recommend his book to any investigator.

Computers and the Life Sciences is a more coherent presentation of an outlook on the uses of computers as these uses might be seen at a university served by a medium-sized computing center. In view of current trends, the university system outlook deserves even more emphasis than it begins to receive here. A good general purpose introduction to computational techniques is hard to write, partly because of the rapid rate at which it becomes obsolescent, partly because of the enormous dispersion of the audience's interest and preparation. Meanwhile, as a work addressed to experimental biologists, Sterling and Pollack's volume has few if any competitors. Although it stresses the problems of closest concern to the authors, and especially the planning of radiation therapy, the volume is sensitive to the familiar languages and work habits of biomedical research generally, and emphasizes analog inputs and statistical processing.

Computers in Biomedical Research, volumes 1 and 2, which calls on the specialized experience of a large and illustrious group of contributors, is certainly the most timely and broadly interesting of the works reviewed here. Most of the authors do not presuppose a detailed background in computer techniques for their readers, and many of the chapters could be read as an introduction to computer applications by specialists in the various fields of biological research. These two volumes edited by Stacy and Waxman already cover a very wide range of topics and points of view. We may hope that they initiate a badly needed, continuing series of state-of-the-art reviews. The chapters are in the main very well written, to the point, and related to the full range of significant contemporary applications: analog to digital conversion and data handling, especially for neuro- and myophysiology; simulations of complex behavior; analyses of chemical reaction chains; and x-ray analysis; but they provide only some glimpses of computer-controlled hospital management, and even less of automated library processes and laboratory routine and of programmed teaching systems. These volumes lay strong emphasis on demonstrated accomplishments, an almost unique virtue in the literature of this fast-moving field. In consequence, however, the reader may not sense the significance of the new systems that are just coming into the field. Versatility of access to the system rather than brute-force computing power is the hallmark of this era, and of course quite indispensable for the general use of the computer as a workaday tool by every scientist in his own laboratory: computational service as a public utility.

In some ways *Mathematics and Computer Science in Biology and Medicine* comes closest in flavor to this anticipa-

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tion of the future which is rapidly becoming the present. As the proceedings of a conference with recorded paraphrases of the discussion, it condenses a great deal of intelligent thought on problems and uses of computers. The expositions on the logical problems of classification, on data systems for hospitals and large-scale vital statistics, and the commentaries on the extraction of significant wave forms make this another indispensable volume on the reading list of any quantitatively minded biologist, even apart from its use in orientation toward computer applications.

The contributions thus give an excellent perspective on the uses of computation for biomedical research. For many biomedical researchers today, the computer's most important uses are perhaps in signal analysis and in x-ray crystallography, and all of these works pay considerable attention to analog processing and digital numerical analysis. For these applications, the digital machine is simulating an analog device which, except for inflexibility in reprogramming, could well outperform the digital machine. Stress on such simulations might obscure the role of the digital computer as an automaton whose fundamental processes are in fact not numerical but logical. Indeed, great ingenuity has had to be applied to achieve the realization of arithmetic operations as complexes of the logical steps inherent in the computer. This concept is of course underlined as an aspect of engineering design, and it is fundamental to Newell and Simon's chapter "Programs as theories of higher mental processes" (in *Computers in Biomedical Research*, vol. 2). Thus, the utility of the computing machine as a numerical analyst may eventually awaken the biologist's attention to an event of phylogenetic rather than historical significance: the emergence of a symbol-manipulating organism which is now well launched on a distinctive evolutionary pathway. If many a human being congratulates himself that his power to turn off the machine is still the decisive fact of this symbiosis, he may be rudely disillusioned—say by a spell in prison—should he violently attack an economic value on which many hundreds of his colleagues depend.

The phylum Automata is evolving rapidly—doubling its general capability at intervals of about 15 months—according to a new set of rules that we dimly understand. Even more consequential than the hardware are the programming systems and languages which have by no means exhausted the capabilities of last year's hardware. With his concern for the forces that underlie organic evolution, the biologist has a special responsibility to understand the phylogeny of automata as a major component of the orthogenesis of the planet. These works are not directed to such ethereal issues, but a by-product of their educational message to biologists is an appreciation of the microscopic anatomy and system physiology which must underlie the ecology of these new organisms.