startling examples of the use of visual imagery in mathematics), they are almost overshadowed by Cooper and Shepard's elegant 100-page study of mental rotation, which goes far beyond Shepard's earlier and already influential work. Among its findings are that subjects cannot rotate an abstract frame of reference, but only an image of a concretely specified form; that certain well-defined circumstances yield nonlinear rotation-time functions; and that people can be induced to rotate a mental image continuously at a regular rate, with predictable effects if a comparison stimulus suddenly appears in the field. At all levels—ingenuity of design, sophistication of analysis, thoughtfulness of presentation—this is an outstanding piece of research.

The book offers two other very competent papers, both using judgment latencies to analyze complex processes. Posner continues to develop his notion of internal "codes," or modes of representation; Clark, Carpenter, and Just study the verbal statements which people find acceptable as descriptions of schematic drawings. In summary, whatever doubts one may have about the ultimate future of experimental psychology, there is no doubt that this volume includes some impressive examples of the present state of the art.

ULRIC NEISSER
Center for Advanced Study in the Behavioral Sciences, Stanford, California

A.I. in EASEy

Pattern Recognition, Learning, and Thought. Computer-Programmed Models of Higher Mental Processes. LEONARD UHR. Prentice-Hall, Englewood Cliffs, N.J., 1973. xxii, 506 pp., illus. $13.95. Prentice-Hall Series in Automatic Computation.

No matter what its ultimate definition, in practice "artificial intelligence" (A.I.) deals with computer programs that can be said to learn, recognize patterns, and solve problems. One usually teaches A.I. by discussing programs that appear to be especially good examples of machine thought. A few authors have tried to develop general principles about the capabilities of classes of algorithms used in A.I. Here Leonard Uhr, one of the major contributors to A.I. research, has tried yet another approach, a guide to the creation of A.I. computer programs. To be sure, Uhr interleaves mentions of general problems with his discussion of specific programming examples, but he usually does not go much beyond a brief aside on a general problem that a sample program illustrates. His asides are not reasoned arguments; his programs are.

Uhr discusses four subfields of A.I.: pattern recognition, game playing, problem solving, and learning. In each case he first presents a rudimentary program to do a simple illustrative task and then complicates it in order to execute more complex varieties of "intelligent action." There are numerous asides about the programs but, as noted, no formal analyses. Neither is there very much coverage of the literature, although there is a good bibliography, divided into topical sections. The programs themselves are written in EASEy, a simplification of the SNOBOL programming language, which Uhr hopes can be read like text. Fortunately, Uhr also offers clear English-language précis of the various EASEy programs. He seldom uses flow charts, and I, for one, missed them.

In evaluating Uhr's work we must distinguish both how well his aims are met and how well they have been chosen. Uhr himself says that the book is unevenly written. The discussion of pattern recognition is quite good, both in the choice of programming examples and the philosophical asides. I recommend this section to anyone who must actually program a pattern recognizer. The chapters on game playing do not contain clear-cut discussions of the various algorithms that have been developed for board games. Uhr has chosen to spend a great deal of time on a general discussion of the game GO, rather than the much more studied chess; his discussion is interesting, but it shortchanges the student who has not already examined the uncited literature. In discussing problem solving Uhr does not explain the basic ideas behind the resolution principle and graph searching. Finally, the most difficult section to evaluate is the one on learning. The examples of learning programs appear, at first glance, to be a collection of useful but ad hoc tricks. Uhr clearly feels that they represent much more. Unfortunately, his failure to carry his asides to the point of formal analysis leaves me unclear about the real implications of the programming devices illustrated. Uhr certainly recognizes the need to trace a connection between learning and pattern-recognition programs. He tries to do this by cross referencing from a discussion of learning to pattern-recognition programs presented earlier, but the effort seems to me to be of limited success.

Uhr's approach to instruction via programming example will probably be very useful in engaging the beginning student in a concrete discussion of A.I. This is good pedagogy and, especially at the undergraduate level, it should be much more effective than reliance upon the more formal, analytic, "removed from the real computer" approaches taken in several other texts. The disadvantage is that students may learn to plunge forward with clever programming solutions without analyzing their algorithms in any formal way. This encourages the software-engineer approach to A.I.—"can I program the machine to solve the problem at hand right now?"—and discourages the search for *proven* general solutions, even though Uhr stresses the need for such solutions in his discussion. The student is likely to heed the examples more than the cautions.

This book is an interesting adjunct to other A.I. texts. At the least it could serve as a second text in a course in which students discussed general principles and, using Uhr's book, worked on concrete programming problems. (A revised edition, written specifically for this purpose, could be much shorter.) A Compleat Artificial Intelligencer will have to contain serious discussions in mathematics, engineering, psychology, and programming. Only the last is given here. Uhr, too, is human. To give four would be divine.

EARL HUNT
Departments of Psychology and Computer Science, University of Washington, Seattle

The Physics of Bonding

Bonds and Bands in Semiconductors. J. C. PHILLIPS. Academic Press, New York, 1973. xii, 288 pp., illus. $18.50. Materials Science and Technology.

During the past six years, J. C. Phillips has worked on modernizing and generalizing the outlook on chemical bonding begun by Linus Pauling, now possible because of the immense increase in factual knowledge about covalently bound solids. The theoretical calculations of conventional solid state theory can be long on computer time