research-oriented monographs, but its usefulness in teaching should extend much longer.

The reason for my delight in reading over the work is the many connections Bekefi makes between the subjects he discusses and physics at large. Research workers in any field—and plasma physics is no exception—easily fall into using a lingo which insulates their work from their colleagues in adjacent fields; here this pitfall has been skillfully avoided.

The treatment centers mainly on the production, transport, scattering, and reception of self-generated plasma radiations. Interactions of the plasma with externally generated signals are discussed insofar as they can illuminate the main subject. Thus, careful development of radiative transport theory is provided, with particular attention to the problems associated with the anisotropy of many interesting plasmas. Kirchoff's radiation law is carefully discussed and its important generalizations to nonequilibrium steady states are developed. At about this point, material subject to straightforward experimental test is introduced, and—setting the tone for most of the remainder of the monograph—the experiments are nicely woven in with the theory.

Careful discussions follow on the emission processes in plasmas—both single-particle and collective. The relevance of the cyclotron emission mechanism, in particular, to both laboratory and cosmic plasmas is stressed. The influence of weak microinstabilities on the emission spectrum is also discussed. Chapters on scattering from plasma fluctuations and on experimental techniques round out the work.

J. L. HIRSHFIELD
Department of Engineering and Applied Science, Yale University, New Haven, Connecticut

Cognitive Paradigms and Real Minds

The Psychology of Communication. Seven Essays. GEORGE A. MILLER. Basic Books, New York, 1967. 207 pp., illus. $4.95.

Six of the essays in this volume have appeared before in various sources, dating from 1956 to 1964. With the exception of the fourth (Concerning Psychical Research) the essays are semi-popular expositions of the problem area in which the author has been an outstanding investigator. Specifically, Miller's concern is with man as an information-processing and information-gathering system.

The enthusiasm with which the mathematically oriented psychologists greeted information theory is understandable on philosophical grounds. A science matures when it acquires a "skeleton" in the form of a paradigm, that is, a conceptual framework on which pieces of theory can be hung so that the science can develop as an organic whole. If a living process involves, in addition to transformations of matter and energy, the processing of information, then the "quantification of information" could well presage a paradigm for psychology analogous to that provided for physics by the quantification of energy. However, the information-theoretical method in psychology has not fulfilled some of the sanguine expectations, for it has shed little light on *how* the processing of information takes place. (Conservation laws would not have been of much help in physiology, if the physiologists had not made use of advanced biophysical and biochemical techniques to discover the details of matter and energy transformations within the organism.) The quantification of information-processing in an actual situation depends not only on the "objective" features of the situation but also, and essentially, on the inherent abilities or previous experiences of the processer. To take a simple example: since an octal digit carries three times as much information as a binary digit, one might think that three times as many binary digits as octal digits could be stored in the immediate memory. It turns out, however, that there is little difference, unless the subject learns to recode the binary into octal digits. Generally speaking, the amount of information that can be stored in the immediate memory and the amount that can be "pumped" through an individual depend crucially on the coding procedures. Nevertheless, the information concept did serve a useful purpose in experimental psychology by bringing this problem into focus.

Miller's first three essays are devoted to this and related problems. Particularly illuminating is the second essay, the justly famous The Magical Number Seven Plus or Minus Two. The third essay, The Human Link in Communication Systems, brings out the "glaring result . . . man's inadequacy as a communication channel," Specifically, the capacity of this "channel," as revealed in experiments designed to measure it, is not more than 25 bits per second, a rate attained by skilled typists and pianists. The lesson is clear: the use of human beings as a "link" is not, as Norbert Wiener would have put it, a human use of human beings. Miller implies the same when he says that "man's peculiar gift . . . is his ability to discover new ways to transform, or to recode, the information which he receives. . . . The search is something we call 'thinking'; if we are successful, we call it 'understanding.'"

The last three essays are devoted to another "modern" paradigm of communication science, namely the approach suggested by the theory of formal grammars. This paradigm rests on a categorical rejection of the conditioned-response model of verbal behavior. An elementary calculation shows that, aside from clichés, the overwhelming majority of sentences which we "understand" and produce have never been heard or uttered before. To invoke the "generalization" of a conditioned response is to evade the problem. The crucial question is *how* we generalize. The psycholinguists of the formal-grammar school postulate an inherent sentence-producing and sentence-recognizing apparatus, unique to our species. Psycholinguistics, as defined by that school of thought, is the study of the modus operandi of the presumed apparatus. In this way a link is made between a theory of verbal behavior and the theory of automata, where a grammatical sentence corresponds to an output produced (or an input accepted) by an automaton and grammar to the rules governing the behavior of the automaton. The experimental techniques in psychology suggested by this model are used to investigate the degree of comprehensibility, acceptability, and reproducibility of sentences as these depend on the complexity of their structure.

In the last essay, the new one in the volume, Project Grammarama is described. This is an experimental program aimed at discovering to what extent subjects are able to infer the rules according to which sequences of symbols are produced, that is, the rules of an artificial grammar. These are experiments in concept attainment analogous to those reported by Bruner, Goodnow, and Austin in *A Study of*

Thinking, except that in that study the concepts were largely categories, whereas in Grammarama they were sequential generative rules. The attainment of the latter concepts appears to be a task of considerably higher order of complexity.

The Psychology of Communication is written in easy, informed style. I can think of no better way to introduce the above mentioned "modern" methods in psychology to the general reader.

I would take issue with Miller's optimistic prognoses on the role of information-processing technology in human affairs. In the sixth essay (Computers, Communication, and Cognition) he easily refutes the popular apprehensions (of mass unemployment and the like). But, he does not touch upon the more serious misgivings expressed, for example, in Norbert Wiener's last book, *God and Golem, Inc.*, in which the theme is idolatry.

ANATOL RAPOPORT
Mental Health Research Institute, University of Michigan, Ann Arbor

A Study in Professionalization

The Mechanical Engineer in America, 1830–1910. MONTE A. CALVERT. Johns Hopkins Press, Baltimore, 1967. 314 pp., illus. $8.50.

Historians are notorious conservatives, and it is encouraging to find signs of a growing academic interest in such historically uncanonical subjects as professionalization, technology, and bureaucratization, forces which have, after all, dominated our society for more than half a century. Calvert's study makes a genuine contribution in all three of these areas. This book is characteristically "modern" not only in subject matter but in organization as well. Its author has been willing to adopt as an integral part of his conceptual and structural framework the generalized characteristics assigned by sociologists to the professions, eschewing both the traditional narrative mode of the historian and the internal subject-matter-oriented approach of historians of science and technology. Calvert has obviously sought to learn something of the nature of professional life, not simply to write about mechanical engineering. Insofar as his subject fails in many ways to fit traditional models of professional life—based as they have been upon law, medicine, and divinity—Calvert's study is all the more valuable, for it provides a series of important insights into determinants of professionalization in a context vastly different from that of the guild-conscious, consultant-oriented world of the lawyer or physician.

The author's general thesis is easily summarized. The history of mechanical engineering in America in these formative generations has to be seen, he argues, as essentially a conflict between two distinct cultures, a "shop culture" originating in the procedures and values of the 19th-century machine shop, and a newer "school culture" centered around the more formal training patterns of the engineering school. The shop-culture leaders, as Calvert sees them, were throughout the century men of good family and established social position, men who had gradually worked their way up through the successive stages of training and acclimatization in the shop, often in enterprises owned by relatives or other family connections. The comparatively small size, moreover, of individual production units in the mid-19th-century machine-tool industry meant that the shop-culture elite would in many cases have to function as businessmen as well as engineers. These engineer-entrepreneurs were naturally leaders in the establishment and in the affairs of the first generation of the American Society of Mechanical Engineers. Calvert contends that shop-culture spokesmen were, moreover, in many ways hostile to or uninterested in the more self-consciously professional stance of the educators and administrators who spoke for the school culture. They had little interest in formal academic standards or explicit ethical codes; for the status of the shop-culture elite was based not simply on their role as engineers and the respect allotted such practitioners by society, but also on their social and business status—factors, that is, extrinsic to their peculiarly engineering function. (Calvert does, however, suggest that the role of mechanical engineer might, in mid-19th century, have provided a means through which gentlemen could find an economically secure place in an increasingly materialistic society yet still maintain some of the professional's dignity and social orientation.) Most of the growing number of engineering-school graduates in the last decades of the century came from lower socio-economic backgrounds and, Calvert argues, had far more at stake in the establishment of an assured professional status. Thus their unhappiness with the desire of shop-culture leaders to keep the ASME as something of a gentleman's private club. Thus the emphasis of school culture spokesmen upon formal academic credentials and their insistence upon the necessity for studying pure mathematics and physics, as opposed to the more intuitive, practice-oriented emphases of the shop-culture spokesmen. This polarity of values explains, for example, the surprisingly sharp turn-of-the-century conflict in the ASME over the adoption of the metric system, an innovation supported by school-culture leaders and opposed by the Society's dominant shop-culture elite, many of whom, as entrepreneurs, might have faced substantial economic costs if the merit system were universally adopted.

Such questions became increasingly unavoidable as the technological and organizational structure of American industry changed; in the late 19th and early 20th centuries it was becoming ever more apparent that the entrepreneurial model was no longer a realistic one for the mechanical engineer. The very great majority, whether trained in the schools or primarily in the shop, would have to assume more or less subordinate places in increasingly large bureaucratic aggregations (in which, ironically, engineers who hoped to occupy the highest seats of power would be those who gave up engineering and entered the managerial and decision-making echelons). The mechanical engineer, unlike the civil engineer, had never been basically an independent consultant; now he was almost always a component part of a decreasingly autonomous production function. It is in this context that Calvert makes a significant reinterpretation of Frederick W. Taylor and the other mechanical-engineering apostles of scientific management. He sees the shaping of this new discipline as an attempt by younger members of the shop-culture elite—of which Taylor was clearly a part— to create a new management role, one in which the engineer might preserve his status and decision-making autonomy, even in a large corporate entity.

As I hope to have suggested, Calvert's study is novel and inherently interesting in its subject matter and in some ways broadly suggestive in its implications. Its method, however, raises a number of questions. Most obviously, the author's decision to rely in only