of Kepler, Descartes, and others at the beginning of the 17th century. Knowing what we know today, one is tempted to be surprised or even contemptuous that a mechanistic interpretation of vision was adopted so slowly, but the problems are by no means solved. We know only a little of the mechanisms at work within the retina in the processing of an image for transmission down the optic nerve and have even less understanding of the subsequent fate of the image. It is healthy to recapitulate the struggle that was necessary to solve the problem of the first steps in vision.

An article by T. Mulvey on "The history of the electron microscope" again gives us a feeling for the pace and character of an important scientific development. It is to be regretted, incidentally, that the fundamental patents of Reinhold Rüdenberg, which are discussed in Mulvey's references (Gabor, Freundlich), were not mentioned. Rüdenberg's priority as inventor was upheld in American courts and, much later, in Germany, though it is clear that commercial secrecy and his difficulties as a Jew in Berlin severely limited the influence of his ideas. Mulvey's paper correctly describes the development of the electron microscope, in which Rüdenberg apparently played no part; but the invention was legally his.

Two papers are devoted specifically to the optical microscope, S. Bradbury on "The quality of the image produced by the compound microscope: 1700–1840," and G. L'E. Turner on "The microscope as a technical frontier in science." Both give valuable new quantitative information about the actual performance of the microscopes available to early users. Papers by J. R. Levene on "The mechanism of accommodation" and Joseph Needham and Lu Gwei-Djen on "The optick artists of Chiangsu" complete the book.

W. LEWIS HYDE
Institute of Optics,
University of Rochester,
Rochester, New York

A Formalism for Quantum Physics

Lectures on Quantum Field Theory. P. A. M. DIRAC. Belfer Graduate School of Science, Yeshiva University, New York; Academic Press, New York, 1966. 159 pp. $7.50.

P. A. M. Dirac, the author of this somewhat puzzling book, is a giant of 20th-century theoretical physics. His name has long been an everyday adjective for physicists who speak, for example, of the Dirac equation, the Dirac delta function, and of Fermi-Dirac statistics. Any teacher of quantum mechanics will sooner or later refer his students to "Dirac's book" (*Principles of Quantum Mechanics*, first published in 1930). In that astounding work, Dirac achieved a definitive and lasting formulation of the new quantum mechanics, almost at the moment of its birth.

The present volume is the record of a series of 32 lectures on quantum field theory given at Yeshiva University in 1963–64. Special emphasis is placed on quantum electrodynamics (the quantum-theoretical version of Maxwell's electrodynamics), the most successful dynamical theory of modern times. Since its foundations were laid by Dirac himself (1926), these lectures are of particular interest.

The book is devoted largely to an exposition of a novel point of view concerning the divergence difficulties of quantum electrodynamics. Dirac believes that the most serious divergence is that associated with the so-called vacuum fluctuation diagrams. He asserts that these terms are simply dropped in the "usual" treatments, unlike the divergences which are handled by mass and charge renormalization, and that "one really gives up all pretense of logical development in places." This point of view leads Dirac to far-reaching conclusions: the Heisenberg picture of quantum mechanics is "good," the Schrödinger picture is "bad," and the two are not equivalent. Furthermore, the state vectors are not elements of a separable Hilbert space.

The overall aim of the lectures is to formulate quantum field theory entirely in the Heisenberg picture, thereby "cutting a lot of dead wood from the usual presentation." The kind of space in which the dynamical variables or q-numbers operate is not specified. For quantum electrodynamics, Dirac makes the "radical assumption" that a physical state corresponds to a q-number rather than to a vector. The interpretation of the new formalism is illustrated in part by computations of the anomalous magnetic moment of the electron and the Lamb shift, but is otherwise left incomplete.

Dirac's opinions regarding the necessity of inequivalent Schrödinger and Heisenberg pictures and the need, in particle physics, for a state space "bigger" than a Hilbert space will probably not be shared by many theorists at the present time. A quite different point of view regarding the difficulties of quantum field theory is expressed, for example, by R. F. Streater and A. S. Wightman in their book *PCT, Spin, and Statistics, and All That* (Benjamin, 1964).

The conversational flavor of the lectures has been preserved, and the reader's enjoyment is enhanced by the realization that he is being piloted through the infinite electron sea by the man who invented it.

J. SUCHER
Department of Physics and Astronomy,
University of Maryland, College Park

A Culture in Mexico

The Mixtec Kings and Their People. RONALD SPORES. University of Oklahoma Press, Norman, 1967. 287 pp., illus. $5.95.

For over 500 years before the Spanish Conquest, the southern Sierra Madre of Mexico was populated by the Mixtecs, a people with a culture characterized by sophisticated gold jewelry and multicolored picture books. While other Mesoamerican cultures have received scholarly attention, the Mixtec has been relatively ignored. The neglect appears strange in the presence of the elements for systematic study which Spores details: accessible archeological sites in abundance, 16th-century documents, and present-day native Mixtecs.

The Mixtec Kings and Their People constitutes a pioneer effort at bringing together some of this material and making inferences from it. The author has visited the sites he describes, and deciphered and translated many of the documents he draws upon from archives in Mexico City and Seville. His conclusions are painstakingly drawn. All this gives the work its authoritative tone.

Although historical documents are utilized extensively, the approach is anthropological: it extracts generalities from the data. The picture that emerges for prehispanic times shows the Mixtecs living in limited valley enclaves in

which they farm bottom lands and artificial terraces. Although nonurban, they duplicate in each valley an elaborate political structure directed by a genealogy-conscious caste. As with the islands of Polynesia, the limited setting of meager resources belies the intricate ranking system. The nobility seems incongruous—a diluted version of something more grandiose. The Mixtecs could have developed their taste for royalty as builders of the classic urban centers of Teotihuacán, Cholula, and Xochicalco, but this is merely conjecture.

Spores eschews conjecture. His history is documented and, therefore, firm. And in avoiding theoretical polemics about the hydraulic factor and the geo-managerial role of the nobility, Spores sagaciously places historical explanation as prerequisite to theoretical understanding.

With the Spanish colonial regime, the hereditary Mixtec rulers are not liquidated. Instead, a new political and economic structure forms gradually as the Spaniards chip away at the land holdings and privileges of the nobility. The emergence of the new plural society is a complex process, its study a complex task. Spores has made an auspicious beginning. The importance of his book lies not only in this, but in pointing the way to further elucidation of problems beclouding the study of the Mixtec.

CHARLES R. WICKE
Universidad Nacional de Asunción, Asunción, Paraguay

Neurobiology

Nervous and Hormonal Mechanisms of Integration. A symposium, St. Andrews, Scotland, September 1965. G. M. HUGHES, Ed. Published for the Company of Biologists on behalf of the Society for Experimental Biology. Academic Press, New York, 1966. 573 pp., illus. $16.50.

This volume contains the proceedings of the 20th Symposium of the Society for Experimental Biology. It presents a diversity of selected topics in the field of neurobiology and related areas and is concerned with integration in the broadest sense. The book is remarkable for several reasons: it is symptomatic of the curious schism that still exists between the medical school physiologists and the physiological zoologists or zoological physiologists. Physiologists of the latter kind are usually labeled "comparative" physiologists, even though it has long been recognized that the comparative approach is the fundamental approach of all physiology.

With very few exceptions the participants in the symposium were chosen from among zoologists. There is not a single representative of a physiology department associated with a medical school. The representation is the more noteworthy because, simultaneously and in competition with the St. Andrews symposium, there was a Symposium of Comparative Neurophysiology in Tokyo, Japan, which was attended by an even larger number of mainly zoologically oriented physiologists. The fact that two somewhat similar symposia have been held on opposite sides of the globe at the same time is a strong indication for the vitality and enterprise of the physiologists interested in the general problems of excitability and the specific problems of the integration of nervous function. It is obvious, however, that we still need a synthesis that will permit an overview of the entire field concerned with the integrative action of the nervous system and that encompasses both the mammalian work and the work conducted on selected but highly successful invertebrate preparations.

The papers presented at the symposium are veritable gems sparkling with information. Each displays many facets of the topic it covers. All participants made it their goal to present their own experimental work in wider contexts, and the individual papers provide excellent introductions to their subjects.

A prologue by the sage of comparative neurophysiology, T. H. Bullock, points out some of the latest developments and hints at future ones. In the first paper, M. A. Sleigh discusses the coordination and control of cilia, concentrating on protozoans and molluscs. The name of v. Brücke is misspelled twice in the article, but this is a minor detraction from the usefulness of a review that covers the older as well as the more recent literature concerning the relation between ciliary beating and membrane permeability, ion effects, membrane potentials, and the action of local hormones. An excellent paper by R. K. Josephson on the mechanisms of pacemaker and effector integration in Coelenterates again summarizes the older literature and points out some of the newer developments. A most welcome paper by T. Sibaoka treats action potentials and electrical aspects of integration in plant organs. The coverage of the literature ranges from 1922 to 1962. Donald Kennedy, W. H. Evoy, and H. L. Fields report on the unit basis of some Crustacean reflexes. These authors analyze the roles of proprioceptive control elements and of intraganglionic "command" neurons, "driver" neurons, and inhibitory connections in the activation pattern of individual motoneurons. Their analysis is based on the pioneering work of C. A. G. Wiersma, who first established that in any nervous system the central nervous system contains interneurons individually equipped to respond to specific sets of inputs. D. M. Maynard presents, in addition to a review of earlier literature, a tremendous amount of new information. He describes several types of integrative units in the lobster brain (among them units that exhibit intracellular delays and "alarm clock" properties) and reports on new experiments on cardiac ganglia and extensive investigations on the stomatogastric ganglion. Wiersma summarizes the ingenious work he and his co-workers have conducted over several years on integration in the visual pathways of several crustaceans. Considering that the analysis includes the interaction of optically controlled events with those dictated by mechanoreceptors and statoreceptors, these investigations offer a deeper insight into the fundamental neurophysiological aspects of vision than any work carried out on vertebrate organisms. In his analysis of optokinetic responses in crabs, G. A. Horridge integrates his recently published studies on the ultrastructure of the optic ganglia. The roles of pacemaker- and oscillator-coupling in the control of rhythmic movements (flight, walking) of insects are the subject of papers by D. M. Wilson and G. Wendler. K. D. Roeder and R. S. Payne have carried the investigations of acoustic orientation of moths further by observing and analyzing the integration of the inputs from the two sense cells in the central nervous system and the modification of the sensory input by the moth's own wingbeat. Chemical sense communication in insects and other animals is reviewed and systematized in a fine paper by D. Schneider. H. M. Gerschenfeld presents an eclectic but very stimulating discussion of current studies on chemical synaptic transmitters in invertebrates. The production and release of hormones from neurosecretory cells is briefly but criti-