rather than culturally conditioned (p. 58) and perhaps (despite denials) people as overly predisposed to be obsessed with the calculus of material profit and loss.

The experience of biology and the physical sciences suggests that some kind of materialist research strategy is probably essential for the construction of far-reaching scientific theories. Most scientists would also agree with Harris that the test of such a strategy lies in the cogency of its theories and that probabilistic theories cannot be falsified by negative instances so long as the latter do not occur with greater-than-random frequency. The cultural materialist theories cited in this work are developed to varying degrees. Harris's suggestion that women played an active role in hunting during the Pleistocene is challenging but remains highly speculative, even though many of his views about human nature are keyed to it. His most elaborated theories, such as those concerning prohibitions against eating pork and the sacred cow complex of India, while carefully researched and potentially falsifiable, remain controversial.

The ultimate acceptance or rejection of these theories will require the collection of vast amounts of reliable quantitative data, in addition to what is already available. This challenge is obviously a strong point of Harris's approach. Yet, as he clearly acknowledges in certain instances, historical and archeological data tend to be quantitatively very weak. Paleodemography, in particular, has moved only slightly beyond the purely speculative. In recent years, the interpretation of archeological data has been heavily influenced by the tenets of cultural materialism, but in most instances assumptions rather than the incomplete and often equivocal data have determined the results. As cultural materialists rely more heavily on archeological findings to test their theories they must guard, perhaps more carefully than Harris has done here, against the dangers of circularity.

The growth of scientific knowledge is a facet of cultural evolution to which Harris pays little explicit attention. Yet he clearly appreciates its importance when he states that it matters profoundly whether people believe a disease to be caused by germs or witchcraft and more importantly when he believes it worthwhile to struggle against antiscientific movements and attitudes. From one point of view, scientific knowledge is profoundly *emic* (ideas in the scientists' heads), but as a basic component of the technology by which a society exploits its environment it is also profoundly *etic* (capable of being judged cross-culturally by an observer). It is also cumulative and diffusable and strongly shapes the image that any human group holds of its environment and of its own nature. In some respects, scientific knowledge plays a role analogous to the Hegelian concept of the growth of rational consciousness. It constitutes a holistic counterpart to Harris's study of the adaptation of individual cultures to their environment and a positive counterpart to his emphasis on the negative effects of diminishing resources. If Childe's later works fall short of Harris's in their relative neglect of demographic and ecological variables, his treatment of scientific knowledge provides a model for the further elaboration of cultural materialism. The real explanation for the gradual abandonment of animal sacrifice may be less close to Harris's theory of increasing protein scarcity than to Childe's explanation that as a result of the growth of scientific knowledge human beings have slowly learned the futility of seeking spiritual ends by material means and material ends by spiritual means.

Harris's concern to stress the preeminent influence of the infrastructure seems to have led him to ignore other significant approaches. While he utilizes the concepts of positive and negative feedback, he makes no reference to general systems theory, which in recent years has made considerable progress in determining the properties that systems of any kind must have in order to function at a given level of complexity. In particular, these properties relate to the flow of information and the management of decision-making. Hence, even if infrastructural forces relating to demography, technology, economics, and environment play a major role in determining the level of complexity of a system and the system's destiny lies in its infrastructural consequences, much of the shape or structure of the social order may be better explained by systems theory than as a response to the infrastructure. Although Harris may be right that determining how individuals process information cannot be an important concern of a science of culture, this does not deny such significance to determining how groups process it. While a concern with general systems theory does not begin from the materialist postulate that human social life is a response to the practical problems of earthly existence, it is clearly not an idealist approach and it cannot be considered evidence of soft-headed eclecticism to employ it where it is useful.

It also seems likely that society may shape its own institutions to a greater degree and in more important ways than Harris admits. For example, much of the Aztec human sacrificial complex (so far as we can understand it from 16th-century Spanish accounts) seems explainable in terms of the self-interested political behavior rather than the nutritional needs of a conquering elite. A network of social relations constituted the preexisting context within which the earliest cultures developed; while culture has transformed society and mankind's physical nature, social relations may be regarded as a central element of cultural evolution, both as a historical precipitate and as a component interacting with total cultural systems. Hence in the long run the looser Marxist definition of the infrastructure (which includes elements of social structure) may prove to be a more viable materialist concept than Harris's one.

Agreement that cultural behavior is potentially understandable and that the materialist approach is the best or only way to understand it does not guarantee full agreement about research strategies. Materialists may disagree about how complex and varied a network of factors must be taken into account in order to explain the similarities and differences in cultural systems. Harris, in his desire to explain "much by little," appears to postulate a high degree of uniformity and regularity. Yet materialists (and others) who view the situation as more complex cannot for this reason alone be dismissed as obscurantists. As Harris advocates, the proof of the pudding must ultimately emerge in the eating. Unlike many other anthropologists, he is in a hurry to serve dinner.

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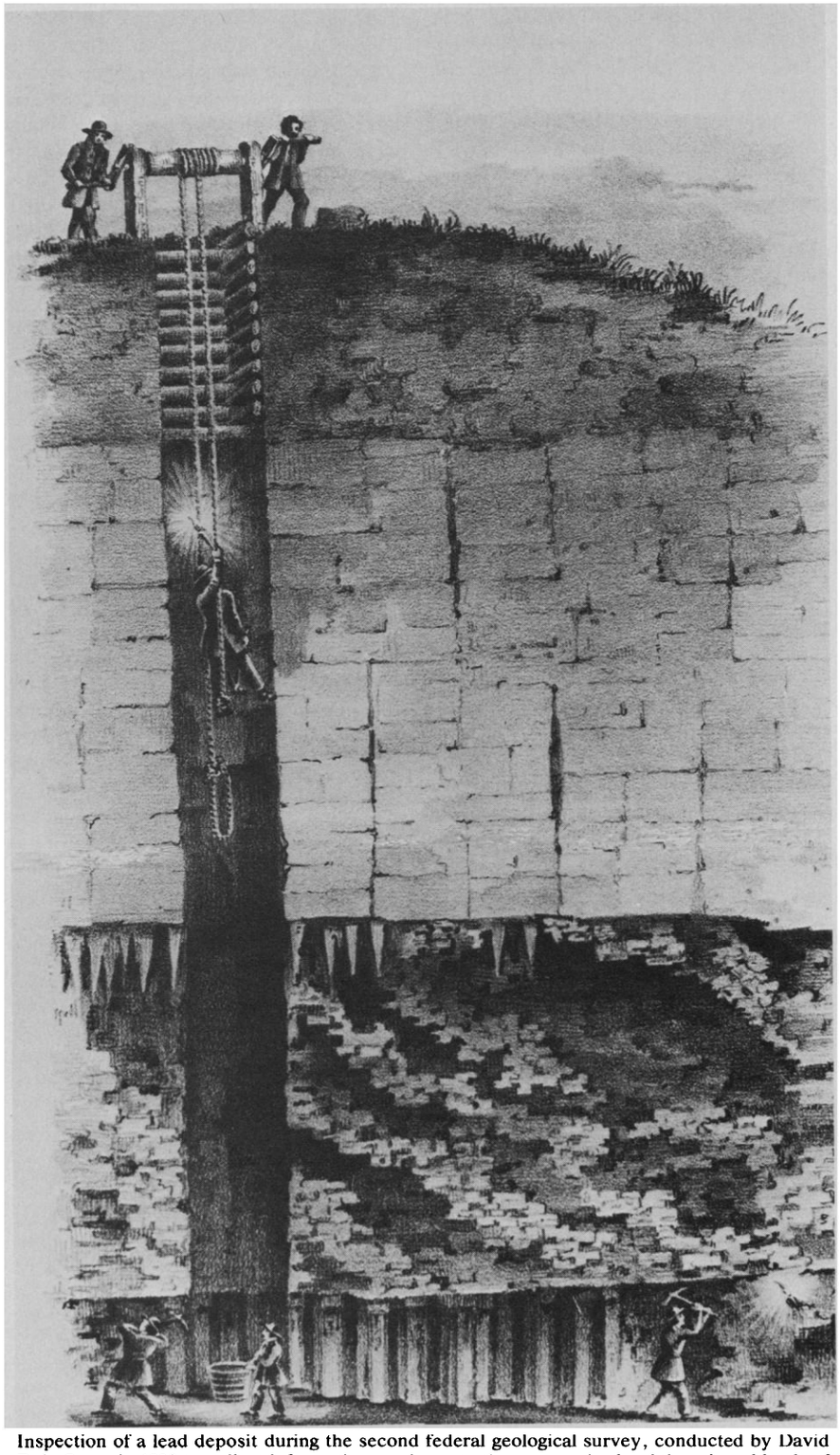
Geologists in American History

Minerals, Lands, and Geology for the Common Defence and General Welfare. Vol. 1, Before 1879. MARY C. RABBITT. U.S. Geological Survey, Reston, Va., 1979 (available from the USGS Branch of Distribution, Arlington, Va., and Superintendent of Documents, Washington, D.C.). x, 332 pp., illus. Paper, $6.

From the work of Hunter Dupree, Nathan Reingold, and other historians, we know that sometime during the middle years of the 19th century geology became a leading American science. Geologists played influential roles in university science, scientific societies, and the



Inspection of a lead deposit during the second federal geological survey, conducted by David Dale Owen in 1839 to collect information pertinent to the proposed sale of the mineral lands of Iowa, Wisconsin, and Illinois. Both miners and farmers wanted the land, and it was necessary to determine just where the mineral deposits lay. "Owen reported that the lead in the Upper Mississippi Valley was almost exclusively confined to the lower parts of the Cliff limestone formation. The ore was usually found in detached masses in the fissure. The deposits often occurred in regularly descending steps, as represented in this sketch, drawn by Owen himself, in which the gangue is dark and the lead ore somewhat lighter. The sketch also shows the mode of drifting and of ascending and descending in the shaft." Owen's general conclusion was that the area surveyed was "one of the richest mineral regions . . . yet known in the world." In addition to lead, it contained copper, iron, and zinc ores. "The survey, he felt, was not only of interest to science but of extreme importance 'in a pecuniary point of view,' to a Government owning hundreds of millions of acres of public lands doubtless containing mineral resources." [Reproduced in *Minerals, Lands, and Geology for the Common Defence and General Welfare*, vol. 1, from Owen's report of the survey, 1844]

publication of scientific journals. They became technical advisers to industry and to government, at the state and federal levels, long before the Progressive period, which political historians usually identify as the time when the scientific expert emerged as policy-maker. Before the century ended, Americans had made contributions to worldwide theoretical geology. The central importance of geologists in the economic, institutional, and theoretical aspects of American science renders any single history of their contributions difficult to write. That difficulty is compounded by the fact that geologists are history-minded, in the literary as well as the analytical sense of the term. They write a great deal of history as well as historical geology. (Bret Harte, poet and storyteller of the California gold rush, is said to have inscribed one of his books, "to Clarence King, author of the *Fortieth Parallel* and other works of fiction.")

In this initial, background volume of a projected four-volume history of the U.S. Geological Survey, Mary Rabbitt has wisely chosen to concentrate upon land, mineral, mapping, and science policy issues and to integrate political and economic activities only as they were related to the pursuit of geology in America before 1879. Within that framework, she introduces detailed evidence in support of the conclusion that geology and geologists deserve a significant place in the history of American science and in the general history of the United States.

The narrative is largely descriptive. Lay readers, for whom the book was written, will be astonished to learn that so many accomplished scientists and their achievements in the field, the laboratory, the mine, the bureau, the club, and the political caucus have been hidden for so long in the specialized sources that make up Rabbitt's excellent bibliography. At the same time, sweeping interpretation and analysis of historical development are de-emphasized in favor of factual reporting, and the rigid chronological structure of the book may cause some readers to lose their thematic bearings.

But the major themes are there, and the central issues are assayed: the early connections between scientific agriculture and the rise of geology; the conflict between applied and basic research, economic and theoretical geology; the concern about the waste of natural resources; the issue of civil versus military science; the contribution of mineral exploration and exploitation to the beginnings of American industrialization. The numerous pictures are a bonus. They il-

lustrate a fascinating part of past American art and trace the evolution of cartographic techniques and geological methods. Let no one say the geologists considered themselves bigger than nature; when they appear in an outdoor picture, they are dwarfed by magnificent landscapes.

Yet the major theme of Rabbitt's study is revealed in the title of her monograph. In fact, her geologists were engaged in the conquest of nature. They received financial support because their investigations promised to deliver practical results. Abram S. Hewitt made the point during debates over the organization of the western surveys: "Nations become great and independent as they develop a genius for grasping the forces and materials of nature within their reach and converting them into a steady flowing stream of wealth and comfort" (p. 279). Although basic research was undertaken in American geology before 1879, "material comfort" was pursued more vigorously than knowledge for its own sake, and the dollar took precedence over the idea. If the geologists whose work is described in this volume are often lost men in the history of science, they are, more unfortunately for our understanding of modernization, lost men in the history of American economic growth.

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The Stellar Life Cycle

Stars. Their Birth, Life, and Death. IOSIF S. SHKLOVSKII. Translated from the Russian edition (Moscow, 1975) by Richard B. Rodman. Freeman, San Francisco, 1978. xiv, 442 pp., illus. $17.50.

This book, authored by a noted Soviet astrophysicist, charts the life history of stars from cradle to grave. Shklovskii beautifully reviews the triumphs of 20th-century astrophysicists in reaching an understanding of how stars evolve. He also manages to include a number of tightly structured chapters in which he discusses the attempts by modern astrophysicists to confront the most poorly understood phases of the stellar life cycle—conception, birth, and death.

Shklovskii's discussions of the physical behavior of the clouds of gas and dust out of which stars form, the mechanisms that may be responsible for triggering star formation, and the early collapse phases of stellar evolution are lucid, although brief. He provides the reader with a good survey of modern work, including the major recent contributions of millimeter radio astronomy and infrared astronomy. Perhaps the book's most impressive chapters are those describing the final stage of stellar evolution. Shklovskii's discussions of stellar explosions, supernovae, and their by-products, neutron stars and supernova remnants, are exceptional for their clarity. He has also written one of the better available introductions to the world of pulsars, black holes, and x-ray binaries.

The book reflects the author's enthusiasm and imagination. He does not fear to share with the reader some of his most deeply held views and his hopes for the solution of vexing problems. This personal touch adds much to the book's liveliness.

Although aimed at a "serious" popular audience, the book is really best suited for those with a solid grounding in elementary physics. Physical scientists of various breeds who want a sound but rapid introduction to the aspects of modern astrophysics covered by Shklovskii will find the book exceptionally readable. It would also serve well as an ancillary textbook in an upper-level undergraduate or first-year-graduate introductory course in stellar astrophysics. The bibliography provides the reader with immediate references, at a variety of levels, to more comprehensive discussions of specific topics.

The translation, despite a few perplexing non sequiturs, appears to preserve a graceful flow. This reviewer found the book a distinct pleasure to peruse.

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Bioluminescence

Bioluminescence in Action. PETER J. HERRING, Ed. Academic Press, New York, 1978. xxvi, 570 pp., illus. $51.75.

In 1952, E. Newton Harvey's *Bioluminescence* was published, and it became the definitive work on the subject. Not only did the book review the entire field, it carefully stated major unsolved problems and put forth speculations. Harvey's book is still unequaled, although an updating is sorely needed. In this collection of review papers Herring has attempted to bring the entire field of bioluminescence up to date. The attempt is commendable, although the field has grown to proportions that preclude a treatment similar to Harvey's.

The book is a good reference for those interested in bioluminescence and a good starting point (after Harvey) for anyone new to the field. It includes chapters on the measurement of light, the chemistry of light-emitting processes, comparative biochemistry of animal systems, and the function and evolution of bioluminescence and many chapters dealing with specific bioluminescent systems. Some of these (chemistry of light-emitting processes, comparative biochemistry of animal systems, bacterial bioluminescence, and the biochemistry of firefly bioluminescence) are essentially repeats of other reviews by the same authors. A proper addition might thus have been a list of "other reviews" relevant to the subject. The chapter on fungal luminescence is disappointing, being primarily a taxonomic treatment of the subject.

The chapters on insects, other invertebrates, dinoflagellates, and fish bioluminescence bring together and synthesize much new information. The chapter by Herring and Morin on the difficult and extensive subject of luminous fishes is particularly good.

Perhaps the most thought-provoking chapter is that of Buck on the functions and evolution of bioluminescence. The evidence in support of many of the existing functional hypotheses (attraction of prey, escape from predators, intraspecies communication, illumination, mimicry, and others) is reviewed and discussed in a comprehensive and excellent treatment of the subject. The stimulating discussion of the origin and possible evolution of luminous systems includes a section on the evolution of symbiotically luminous systems. Much of the discussion in the chapter places other parts of the book in perspective, and this is the chapter that should be read first.

The book suffers from several problems: the styles and goals of the various authors are not united by a common editorial policy; the material is generally poorly indexed (it is often difficult to find specific information such as spectral maxima or kinetics of light emission, and there is no author index); and the all-inclusive bibliography is ponderous and hard to use with the individual papers.

Overall, however, the book achieves its goal, and it should be a part of the personal libraries of all those working in the field.

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