Debris from chert production was concentrated near elaborate houses, but utilized pieces, including imported cherts, were more evenly distributed. Wright suggests that the ubiquity of imported cherts indicates that all households had access to a single import source. Chert production in the Jemdet Nasr Phase was not localized, export production was high, and imported cherts were quite rare, but different varieties were found in association with different houses, suggesting more than one import system. Bitumen production during Farukh times was not intense and was concentrated near small houses. Some bitumen may have been exported. Bitumen production varied considerably, but at a relatively high level, during Jemdet Nasr times and was most intense around the more elaborate buildings. The export ratio was relatively high.

In summary, it is evident that production for export was significantly more important during Jemdet Nasr times, and, although chert imports were at a low level, a great variety of other imported items were present in quantity. Clearly the Jemdet Nasr Phase was more prosperous and the economic system associated with this prosperity was more complex than the Farukh system. Social ranking, indicated by variation in the quality of domestic architecture, was present in both phases. However, Wright argues that high status in Jemdet Nasr society had very broad implications, including control over bitumen export production and virtually exclusive access to rare foods, such as birds and marine fish, and to high-value imported materials, such as lapis lazuli and metal. Administrative artifacts were not found in either phase, with the exception of a single possible seal in each, but Wright assumes that administrative activities, evidenced by sealings and bullae during Uruk times, continued to be pursued in Jemdet Nasr times.

In his final remarks Wright returns to the themes stated in his working propositions and concludes that efforts to reorganize export production began in Uruk times but were not successful until Jemdet Nasr times. Since administrative artifacts were present during the Uruk Phase, the order of his second proposition is reversed. Further, the growth of central towns characterized by specialization of production also seems to occur during Jemdet Nasr times and thus follows the formation of the state, which Wright still considers to have occurred during the Uruk Phase.

The preceding summary touches only the main themes of the Farukhabad report; many interesting topics such as Wright's proposed "design grammar" for Jemdet Nasr polychrome ware, the analysis of beveled rim bowls contributed by Anne Miller, and several informative technical or typological studies are not discussed.

It is difficult to provide an overall evaluation of a work with so many facets. One can only praise the comprehensive presentation of provenience data, the extensive tabulation of metric data on all classes of finds, the use of density measures in analysis, and the careful use of nonparametric statistics to evaluate the significance of artifact correlations and metric variation. The description of stratigraphy is thorough, although one might have expected a more vivid description of the processes by which the strata accumulated. Features and artifacts are well described and well illustrated, although the architectural plans are much too small and the labels are sometimes difficult to interpret. About half of the volume of material excavated was screened, but the tabulation of provenience and analytical units in appendix A does not in all cases unequivocally state which units were screened, a serious impediment to analysis by other scholars of the data presented.

Beyond these comments the Farukhabad report raises issues that must be confronted by any archeologist engaged in research on complex societies. These issues concern both sample size and sample bias.

The size of operations, two 5 by 14 meter trenches and one 1 by 17 meter trench, and the volume excavated, 520 cubic meters, constitute by no means an insignificant accomplishment for a staff of five supervising 30 workmen in a single season. Wright states his conviction that the size of the openings, with the exception of the narrow trench, was adequate and that Farukhabad is not a suitable site for horizontal exposure. Be that as it may, one of the most commendable aspects of this monograph is the scrupulous candor with which Wright reports problems in data recovery, possible sample bias, and, on page after page, reservations concerning the size of the samples. Yet in the end questions about the adequacy of the samples still cast a shadow over many of the conclusions. In my opinion this is not a fault to be laid entirely at Wright's feet; he was working within a system that is poorly organized to support complex archeological research conducted according to contemporary standards. We are certainly all aware that grand expeditions such as the Ur or the Diyala excavations are no longer either theoretically justifiable or financially possible. Nevertheless, it is unreasonable to believe that intensive data recovery and sophisticated quantitative analysis will always compensate for reduction in the scale of excavations. It is clear that a relatively modest increase in funding, devoted to an increase in the scale of excavations during the single season at Farukhabad, would have been amply justified by the stated research objectives and would have been cost-effective.

One can only hope that the Farukhabad report, with its broad scope and interesting, though tentative, conclusions, will stimulate constructive discussion of this problem among archeologists, and particularly within the institutions that support archeological research.

WILLIAM M. SUMNER
Department of Anthropology,
Ohio State University,
Columbus 43210

A Scientist and Reformer

Charles Babbage. Pioneer of the Computer. ANTHONY HYMAN. Princeton University Press, Princeton, N.J., 1982. xvi, 288 pp. + plates. $25.

The 1830's were the years of the Great Reform Movement in Britain. British liberals, inspired by the reforms in Napoleonic France, initiated wide-ranging reforms to social, political, and scientific institutions. Valuing rationality over authority, they called upon science to set its house in order and apply its skills to the improvement of society.

Charles Babbage, who shared these liberal convictions, believed that science was the answer to social problems, but only if science itself was strong. In fact, he was the most prominent reformer of science of the time. He was a founder of the Cambridge Analytical Society, which both catalyzed educational reform at Cambridge and renewed British mathematics by introducing the effective analytical methods used on the Continent. He was a leader in restructuring the aristocrat-laden Royal Society and in bringing organization to science outside London through establishment of the British Association for the Advancement of Science. He encouraged the development of specialist scientific societies, including the Statistical Society, of

which he was the major sponsor. His book *The Decline of Science in England* was largely responsible for legislative reform of British science.

Babbage also stands out for his commitment to the application of science on behalf of society. He developed the techniques of operations research to apply to the problems of the post office, the railroads, and the factories. He was the inventor of numerous industrial processes and equipment and consultant for many more. More than any other scientist of the time, he was familiar with current industrial practices and was well known to most craftsmen interested in extending Britain's fortunes of the industrial revolution through the application of science.

One of Babbage's inventions, the one by which he is best remembered, on which he spent the most effort and expense, and which is the main focus of this book, is his computing machinery. Actually, he conceived two distinct machines, the difference and the analytical engines, as well as various refinements of each. The difference engine, steadily improved from its conception in 1820, was a machine capable of mechanically calculating polynomial expressions by means of the method of finite differences. The analytical engine, first conceived in 1834, was a mechanical computer theoretically equivalent in processing ability to the general-purpose, stored-program computer of today. Neither machine was fully constructed, and only a section of the difference engine was ever working during Babbage's lifetime, owing to problems of finance, lack of government support, shortage of talented craftsmen, lack of precision in manufacturing skills, and ambitiousness of scale of project.

Hyman's main intention in this biography is to explicate the development of what he considers Babbage's primary concern, his computing engines. In this, he has but mixed success. He does not discuss the mathematical or mechanical details by which the engines were to be constructed and to operate. The lack of these details will be a serious disappointment to the scientific reader. Fortunately, the author is much better at detailing the complex political machinations over the government's responsibility to finance construction of the engines and the significance of this issue to the evolution of the British government's policy on the support of science and technology. The book is useful as well in providing the best available chronological accounting of Babbage's work on the engines and for its inclusion of numerous illustrations and blueprints of the machines.

Superficially, this work has the appearance of an intellectual biography and appears to follow the standard canons of academic biographies. It is well footnoted and includes a thorough, annotated bibliography. The reader is quickly impressed with the wealth of information about Babbage and his circle of friends that Hyman collected over a number of years. Unfortunately, the structure belies the author's apparent intentions. Hyman seems to have included every scrap of information he has located and is often led far from his theme. He includes far more than is warranted or interesting about the lives of Babbage's family and close associates and clutters the text with irrelevant anecdotes for entertainment value.

The historian will be disappointed with Hyman's scholarly analysis. He makes a number of interesting and controversial claims about British and Continental science, often contrary to current historical consensus, without providing adequate argument or fact to support them. In the first chapter, for example, he claims that 18th-century British science was not as stagnant as current scholars believe; that before the 1830's there was no clear line demarcating science from technology; and, ignoring for example the 18th-century engineering schools, that not until Napoleon's time was science seriously employed for practical aims. All these claims are made without an attempt at substantiation.

The book is considerably more successful at portraying the social and intellectual life of the intellectual and political elite in Britain and on the Continent from 1820 to 1860. Babbage traveled widely and was familiar in literary and political as well as scientific circles. His associations with William Herschel, Louis Napoleon, and Charles Dickens, for example, are ably illustrated and punctuated by charming anecdotes. Though the book does not accommodate the scientist's interest in technical details, studiously ignores Babbage's pure scientific and mathematical accomplishments, and is less than satisfactory for the scholarly historian, it does provide several pleasant evenings of reading and paints a detailed portrait of the interchange of science, technology, and intellectual life of Babbage's time.

WILLIAM ASPRAY
Department of History of Science, Harvard University, Cambridge, Massachusetts 02138

Celestial Mechanics

Applications of Modern Dynamics to Celestial Mechanics and Astrodynamics. Proceedings of an institute, Cortina d'Ampezzo, Italy, Aug. 1981. VICTOR SZEBEHELY, Ed. Reidel, Boston, 1982 (distributor, Kluwer Boston, Hingham, Mass.). xviii, 374 pp., illus. $43.50. NATO Advanced Study Institutes Series C, vol. 82.

Celestial mechanics contains a diversity of research interests ranging from practical problems of astrodynamics and orbital mechanics to theoretical dynamics. Yet these proceedings of a NATO Advanced Study institute highlight certain themes uniting these different topics.

A welcome aspect is that the papers are, for the most part, expository surveys of recent developments in the field, not research reports. Nevertheless, I seriously question the advertisement that this work is "suitable for use as a textbook in graduate and advanced undergraduate courses in the fields of astronomy and aerospace engineering"; it requires more sophistication than that. (Advanced graduate students could handle some specialized topics.) On the other hand, although the title implies that the book is intended for a certain interest group, other researchers may find it of value.

Several themes unite the "theoretical" and the "practical" papers in the book, and one is random behavior—ergodic and chaotic motion. A selective theoretical survey of this topic is contained in a paper by R. W. Easton on "twisted link mappings." He reviews his own and others' research concerned with the existence of orbits in which the closure of the orbit has positive Lebesgue measure and with maps that are close to twist maps. A related paper by T. Petrosky and I. Prigogine examines the Kolomogorov-Arnold-Moser invariants in light of the statistical mechanics developed by Prigogine and his co-workers. L. Galgani examines the dynamical foundations of classical statistical mechanics. The practical applications of some of these ideas are underscored in a paper by J. D. Hadjidemetriou in which he discusses destabilizing factors in planetary and asteroidal orbits and in a paper by Szebehely warning of some of the practical difficulties caused by problems in celestial mechanics. Somewhat related is a paper by O. Gürel, which is a review of part of the developing subject of dynamical bifurcation (for example, the Lorenz attractor in turbulence theory and the Rossler attractor. As a balance