nance structures found in atomic and nuclear cross sections, to use them to map out analogous structures, and to pursue what Victor Weisskopf called the "third spectroscopy." On the other hand, since the new physics concentrated on the pointlike constituents (the quarks) within the hadrons, its experiments were designed deliberately to screen out the large soft-scattering cross sections. It also turned out that color gauge theory is much easier to apply to hard than to soft scattering.

One of the most striking predictions of the electroweak theory is the "neutral current" of weak interactions, one example of which is the scattering of a muon neutrino from an electron. It is difficult to establish neutral currents experimentally because the neutrino is effectively invisible. The elimination of "background events," which might be confused with the desired signal, poses problems. If one is too stringent in admitting events as real, out goes the baby with the bath water. If one decides that an event counts, that may be self-delusion. This paradoxical situation with respect to neutral currents has been studied in detail elsewhere by Pickering (and by Peter Galison), and Pickering uses it to support his assertion that physics is constructed by making a series of such "irreducible" choices. However, even if the neutral-current example were typical of practice in high-energy physics (which it is not), the whole of physics made this way might still have more validity than the mere sum of its parts. In most scientific research, the requirement is to find a signal in a noisy environment. Though no one claims that this can be done without occasional error, it is not impossible ever to succeed.

Current high-energy physics is described by Pickering as a "satisfying symbiosis" of theory and experiment, characterized by an agreement not to study any problems that do not have a gauge-theory relevance—that is, by a kind of conspiracy. Pickering's arguments are clever but do not convince. Recall, as a historical parallel, Ernest Marsden's observation in 1909 of rare hard-scattering events in the bombardment of a gold foil with a beam of alpha particles. Ernest Rutherford, his professor, used those observations to deduce the structure of the nuclear atom. That marked the beginning of modern atomic *and* nuclear physics and taught physicists the lesson that hard-scattering events are most revealing of inner structure. Whenever that is your goal, it is appropriate to explore that possibility, provided it is technically feasible. That is the motivation for higher-energy particle accelerators and more sensitive detectors, and not an arbitrary agreement. (The model of high-energy physics that Pickering calls "opportunism in context" is on much safer ground, but it is not developed.)

By the same token, I reject Pickering's claim that modern experimental designs enforce an intellectual incommensurability between the old and the new physics. (But in comparing the scale of the tabletop experiments in Rutherford's Cavendish laboratory with the analogous experiments at Fermilab or CERN, we *may* approach incommensurability.) Were we to reject totally the claim of the "scientist's account," that nature itself constrains both experimental practice and its theoretical interpretation, as Pickering would have us do, then we should also be prepared to reject the actual existence not only of quarks but also of atoms and their nuclei (and of tables and chairs as well).

LAURIE M. BROWN
Department of Physics and Astronomy, Northwestern University, Evanston, Illinois 60201

Phenomena of Nuclear Physics

Treatise on Heavy-Ion Science. Volumes 1–4. D. ALLAN BROMLEY, Ed. Plenum, New York. Vol. 1, Elastic and Quasi-Elastic Phenomena, 1984. xxii, 753 pp., illus. $95. Vol. 2, Fusion and Quasi-Fusion Phenomena, 1984. xviii, 734 pp., illus. $95. Vol. 3, Compound System Phenomena, 1984. xx, 589 pp., illus. $89.50. Vol. 4, Extreme Nuclear States, 1985. xx, 701 pp., illus. $92.50.

Heavy-ion physics—the study of collisions with accelerated nuclei from atoms more massive than helium—has come to dominate nuclear physics research in recent years. In an attempt to provide a definitive treatment of the subject D. A. Bromley is compiling a seven-volume collection. The size of the project is not surprising considering the complexity of the field and the diversity of the phenomena involved. Unfortunately, there is no overall scientific editing of the independently written chapters. Nevertheless, the size (nearly 3000 pages so far) and scope of this work make it noteworthy in the literature of nuclear physics.

Bromley introduces the subject with a 130-page historical survey of heavy-ion physics. The initial impetus for the study of collisions between heavy nuclei came with the development of the hydrogen bomb around 1950. Scientists feared that a hydrogen bomb explosion might initiate a chain reaction in the atmosphere, fusing the nitrogen nuclei. Theoretical studies by G. Breit convinced the developers of the bomb that their fears were groundless, but it became apparent that they didn't understand enough about nuclear collisions and that they needed new accelerators to improve experimental knowledge of the subject. More recent motivations for the study of nuclear collisions have been the quest for superheavy atoms, which the military was also interested in, and most recently the search for new forms of matter.

Bromley records the development of laboratories at different institutions and the advances in the design of their accelerators that permitted the new machines to collide nuclei at ever higher energy. He dwells on the institutional aspects of the field's development more than on the scientific discoveries themselves. The introduction provides a view of a large-scale scientific enterprise by a protagonist in the field but not a coherent introduction for someone trying to learn about the physics.

Heavy-ion physicists divide the nuclear collisions they study into categories depending on how much energy is lost in the collision, and the division of chapters follows this scheme. The different categories are: elastic scattering, in which no energy is lost at all; quasi-elastic or direct reactions, in which little energy is lost and the target and projectile nuclei are left almost unchanged; strongly damped collisions, in which the nuclei lose most of their energy while still retaining their identity as separate nuclei; and fusion, in which the nuclei coalesce into one large nucleus.

The concepts of potential and of random motion are crucial to an understanding of the different types of collisions. A potential is a field that governs the deflection or absorption of particles. Potentials are used to analyze elastic scattering and direct reactions between nuclei. The idea of completely random behavior governed by the laws of statistics is applied to the strongly damped collisions.

The technical chapters on the different kinds of collisions are uneven in style and focus. For example, the chapter on elastic scattering makes only passing reference to the basic potentials and emphasizes instead a phenomenological approach. However, one of the chapters on direct reactions gives a broader perspective. A discussion of the elegant connection between quantum theory and classical scattering may be found there, applied to both elastic and inelastic reactions. Phenomena well known in optics as Fraunhofer diffraction, Fresnel diffraction, and glory scattering are observed in nuclear collisions and interpreted with the nuclear and Coulomb potentials.

Most of the chapters are devoted to the more violent collisions, which result in large energy losses or perhaps fusion of the two nuclei. The comparison of quantum potential theory, called time-dependent Hartree-Fock theory, with the empirical observations is well covered. Potential theory has mixed success for violent collisions; some observables, such as the fusion probability, can be explained, but others, such as the correlations between different measurable quantities, are incorrectly predicted. There is a large body of data on these correlations, and better success is found in interpreting them with classical concepts such as friction.

The physics becomes simpler for the fused nuclei, which are formed with a lot of internal energy that must be dissipated one way or another. The details of how this energy is dissipated, by emission of neutrons, gamma rays, and the like, are very well predicted by a statistical model that is presented in a "how-to" chapter explaining the use of the model. Statistical theory has old roots in nuclear physics and has recently been widely applied to describe chemical reactions. The new kinds of data appearing from heavy-ion collisions show that the model is applicable to a much broader range of nuclei and energies than previously suspected.

Additional chapters review the efforts to make superheavy nuclei and to observe new forms of matter at high energy and density, goals that have continued to be elusive. And what about the original impetus to study heavy-ion collisions, the fusion of nitrogen nuclei? Although not mentioned in the chapters, this particular reaction is described well by potentials and by the statistical model.

Finally, the reader should not be misled by the title word "treatise," which implies a systematic exposition. In fact the chapters are uncoordinated, often duplicated, and lack cross-referencing. Also, much of the material dates from mid-1981, so recent developments such as the discovery of element 109 in 1982 are relegated to footnotes or not mentioned at all.

G. BERTSCH
Department of Physics and Astronomy, University of Tennessee, Knoxville 37996

Marine Geology

The Geology of the Atlantic Ocean. K. O. EMERY and ELAZAR UCHUPI. Springer-Verlag, New York, 1984. xx, 1050 pp., illus., + charts. $98; charts alone, $45.

A few generations ago one could have synthesized the known geology of the entire Atlantic in a few pages. Today even a 1000-page tome like this one is not complete. The book probably marks the first and last time such a synthesis is attempted in a single volume at a scholarly level of detail.

Emery and Uchupi have tried to achieve a "broad synthesis" that they hope "may form a sort of plateau above which later studies can rise." Their intended audience is "mainly marine geologists and geophysicists" of all sorts. Not surprisingly the book is bountiful and polished in those areas in which the authors, both marine geologists, themselves have specialized—physiography, sediments, coastal processes, and the structure of continental margins. Among the strengths of the volume are thorough discussions of the Gulf of Mexico, the Caribbean, the continental shelves, and the coasts. The authors seem equally at home on land and under the sea. They also appear to be at home with other aspects of the subject, providing the reader with fascinating if sometimes digressive background on exploration of the Americas, mythology, and modern uses of the sea, including the nongeological. For example, one can read in this geology book about the Battle of Salamis fought in the Mediterranean in 480 B.C. and discover that sunken statuary is probably the most valuable sea-floor resource per unit weight. The discussions of petroleum reserves and the Law of the Sea are likely to be widely read for background information.

Each of the 5000 items in the bibliography is a separate doorway to some aspect of the Atlantic Ocean and its bounding continents. A number of these doors are rarely opened, and the volume may have saved some of the cited articles from oblivion.

The bibliography is so comprehensive, however, that the omission of several works of regional synthesis is conspicuous: a geological-geophysical atlas of the North Atlantic by P. R. Rona, a colored chart of bathymetry and plate tectonic evolution of the North Atlantic by R. K. Perry and others, colored maps of sediment thickness and depth to basement in the western North Atlantic by B. E. Tucholke and others, and the ongoing "Decade of North American Geology" project.

There are other gaps in the book. Relatively few pages are devoted to the igneous crust and the volcanic processes that have created it, and there is scarcely any mention of the submersible "field trips" into the mid-Atlantic Ridge rift valley. Among the 399 figures there is not a single photograph of the ocean floor or of any rock, sediment, or organism recovered from it. There is also little mention of seismicity, and no discussion of how earthquakes reveal the state of stress in the Atlantic lithosphere. Contour maps showing the thicknesses and speeds of seismic waves in several layers of the Atlantic oceanic crust are premature and probably misleading, given the limitations of the data. (In any case, the traditional "layered" crust is now largely considered a convenient construct rather than a reality.) The structure and composition of the Atlantic islands are not treated in any systematic way. This is particularly unfortunate in the case of Iceland, on which the mid-Atlantic Ridge "oceanic crustal factory" can be investigated with nothing more than strong boots and warm clothes. Regional variations in isotope and rare-earth chemistry in mid-Atlantic Ridge basalts are not mentioned even though some of the most exciting results in recent years have come from this field.

The volume is accompanied by a set of some 23 black-and-white charts, of which 11 pairs are Mercator charts covering the North Atlantic (5°S to 60°N) and South Atlantic (5°N to 60°S) and the 23rd is a pre-drift schematic reconstruction showing pre- and syn-rift geologic features. Each chart is a manageable piece of paper (85 by 55 centimeters). The information is portrayed clearly and boldly on the charts, as it is in the figures in the text. No magnifying lens is needed. The set of charts can be purchased separately, and marine geologists will want to order a spare set to take into the "field."

The Mercator projection is ideal for plotting points and tracks of constant heading, Mercator having designed it for that purpose. However, any attempt to display data from a part of the earth as large as the Atlantic on a flat piece of paper involves distortion, and, on the projection used by Emery and Uchupi, a feature of a given size appears 100 percent larger at the northern and southern limits than it does at the equator. Portraying the continuation of the Atlantic through Iceland and into the Arctic would be quite hopeless on such a pro-