Normandy beachheads and in the successful defense of London against buzz bombs. In 1943, the 3-cm "X band" radar "bomb sight" (using a card-programmable computer!) got the 8th Air Force back into the air and bombing through overcast skies. Wherever the war continued, Rad Lab-designed radars were sure to go, accompanied as needed by Rad Lab personnel.

Quite properly, Conant emphasizes the key work of Loomis and Luis Alvarez—whom he appeared to consider a surrogate son—to develop ground control of approach in blind landing. However, she emphasizes pilot-controlled landing with a beam. Loomis and Alvarez's dream was to achieve true control of landing from the ground without pilot intervention. The dream was unrealized despite David Griggs's prior riding of the SCR-584 beam in blind landing. Exocet missiles later rode the same beam. Nonetheless, the elegant ground-control system initiated by Loomis did much for military science but is not seen in commercial airports, where pilot-controlled instrument landing systems (ILS) took over. Ironically, ILS uses the phase system as in Loomis's radar!

With some exceptions, Loomis could spot a winner in finance, in science, and among people. Conant correctly portrays this brilliant and interactive financier and scientist, who had a decisive impact on radar. You will not set the book down until you complete it.

Britton Chance
University of Pennsylvania
Philadelphia

At the Frontier of Particle Physics: Handbook of QCD

Edited by M. Shifman
Volumes 1–3:
World Scientific, River Edge, N.J., 2001. $240.00 (set) (2151 pp. set). ISBN 981-02-4445-2 (set).

Volume 4:
World Scientific, River Edge, N.J., 2002. $88.00 (384 pp.). ISBN 981-238-028-0

What constitutes frontier science? The question is implicit in the title of this unique collection of essays, *At the Frontier of Particle Physics: Handbook of QCD*. Quantum chromodynamics is the field theory that describes the strong interactions in today's standard model of elementary particles and forces. The editor of these volumes is Mikhail Shifman of the University of Minnesota, formerly of the Institute of Theoretical and Experimental Physics (ITEP) in Moscow. Shifman's many contributions to quantum field theory have deeply influenced our understanding of QCD.

Including the new fourth volume, the handbook contains 40 technical articles by well-known researchers, preceded by a section of historical reminiscences and essays, some previously published. The first few of these reminiscences are appreciations of the distinguished scientist for whom the set is a festschrift, Boris Ioffe of the ITEP. The historical section includes a memoir by Ioffe. That memoir and one by the physicist and human-rights activist Yuri Orlov offer windows to the world of Soviet physics in the early cold war period, and recall the role of strong-interaction physics at the opening of the nuclear era. Those memoirs are followed by a number of personal recollections relating to the discovery of QCD in the early 1970s. An essay in the fourth volume recalls the single-minded pursuit of science in and around the school of Lev Landau.

The standard model, which includes QCD, is nearly universally recognized as at once a triumph of 20th-century science and a prison out of which a new chapter in particle physics is struggling to escape. In that context, the title for this huge collection of essays is a provocative one. In his introduction, Shifman opines that QCD is the "only heir" of particle physics. One need not fully agree with Shifman's metaphor to appreciate the view that experimentally grounded quantum field theories have a dignity equal to that of their still-speculative progeny, such as string theory. That perspective enables Shifman and his collaborators to find frontiers of the unexplored territory of QCD within the standard model.

And what a wide territory it is! The 40 articles, organized into 11 parts, wend their way through this protean theory as it changes its guise with the length scale at which it is probed. The parts of the text are organized according to the historical order in which the techniques they describe matured, with the historical overviews as part 1. Volume 2 begins with part 4, volume 3 with part 6, and volume 4 with part 9.

At the conceptual center of QCD is its formulation, in 1973, in terms of quarks and gluons within one of the nonabelian gauge theories introduced by C. N. Yang and Robert Mills in 1954. Subsequent decades have seen progress in following the quarks and gluons that are created in very high-energy scattering experiments through their evolution into the hadrons that are observed in the laboratory. Parts 3 and 5 describe aspects of the "perturbative" expansion for QCD, in which calculations are organized by the number of quark–gluon interactions. That expansion suffices to describe the first stages of the evolution, but only by including states with unlimited numbers of gluons. As parts 4, 10, and 11 make clear, at yet longer time and length scales, one discovers the extraordinary complexity of the QCD ground state. Rather than being a space empty of quarks and gluons, this state appears to consist of a complex assembly of quantum condensates related to the physics of superconductors. Here we enter the realm of "nonperturbative" QCD, in which quarks and gluons organize themselves into collective degrees of freedom. Within QCD, such relationships between emergent phenomena and fundamental structure are pervasive and intimate.

No way is known to solve exactly for the ground state of QCD, although that state can be modeled by use of simplifying assumptions that depend on the physical phenomena to be studied. For example, to investigate the generation of mass, one may give preeminence to the quantum-mechanical tunneling processes of QCD, called instantons. To study how quarks are confined in hadrons, one may emphasize QCD's magnetic vortices. Properties of hadrons and hadronic reactions, discussed in parts 6 and 9, are amenable to a variety of systematic approximations, especially when the hadron or reaction involves one or more "heavy" charm, bottom, or top quarks. To describe those properties, all these regimes require, in contemporary parlance, "effective theories" tied together within the larger theory. Understanding the "duality" relations among these theories, discussed in parts 6 and 7, is perhaps the grandest challenge of QCD.

The variety of QCD effective theories is, as Shifman notes, a tribute to the richness of the theory itself. As discussed in part 10, lattice QCD attempts to reconstruct correlation functions and spectra from first principles, but effective theories also play a key role in truncating the full complexity for practical applications. Part 2 engages "chiral perturbation theory," one of the oldest and most successful effective theories. Chiral perturbation theory, which predates QCD, was originally developed for pions and is now seen as a consequence of the approximate symmetries of QCD within the standard model. Still further removed from quarks and gluons are analogous efforts to describe nuclear physics. Part 8 of the handbook discusses strong interactions at high temperatures and densities. Understanding such interactions—with their astrophysical implications—is the goal of the contemporary program of colliding heavy nuclei. Part 7 describes how, in extended versions of QCD with supersymmetries, one can answer the questions of duality that are so difficult within QCD itself.

There is, of course, no way to do justice in a review to the research distilled in this weighty handbook. No other single document brings together such a broad range of expert perspectives on QCD. The historical articles are interesting and, in places, riveting. However, the work contains no pedagogical introduction to QCD, and the technical articles require that a reader have a substantial background—at least the equivalent of graduate courses in quantum field theory and elementary particles. Shifman and his collaborators have tried to make the presentations self-contained, but that goal is not completely attainable in articles between 20 and 100-plus pages on quite advanced subjects. Nevertheless, a practitioner in any field-theory discipline, even—or perhaps especially—a beginning practitioner, can spend rewarding hours delving into these descriptions.

At the Frontier of Particle Physics will remain useful for a long time, even though it is likely that none of its articles represent the final word. In another decade, when QCD is 40 years old, perhaps many of the approaches described in these volumes will be supplanted by more elegant insights, and some cherished assumptions may even turn out to be wrong. After all, we should expect the unexpected at the frontier.

George Sterman
Stony Brook University
Stony Brook, New York

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Astronomical Image and Data Analysis. J.-L. Starck, F. Murtagh. *Astronomy and Astrophysics Library.* Springer-Verlag, New York, 2002. $64.95 (289 pp.). ISBN 3-540-42885-2

Astrophysics of the Diffuse Universe. M. A. Dopita, R. S. Sutherland. *Astronomy and Astrophysics Library.* Springer-Verlag, New York, 2003. $69.95 (439 pp.). ISBN 3-540-43362-7

Classical Nova Explosions. M. Hernanz, J. José, eds. *AIP Conference Proceedings 637*. Proc. conf., Sitges, Spain, May 2002. AIP, Melville, N.Y., 2002. $198.00 (590 pp.). ISBN 0-7354-0092-X

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Extragalactic Star Clusters. D. Geisler, E. K. Grebel, D. Minniti, eds. *International Astronomical Union Symposium 207*. Proc. symp., Pucón, Chile, Mar. 2001. Astronomical Society of the Pacific, San Francisco, 2002. $95.00 (778 pp.). ISBN 1-58381-115-X

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