ITEP Lectures on Particle Physics and Field Theory, Vols. 1 and 2

M. A. Shifman

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Mikhail A. Shifman's two-volume *ITEP Lectures* . . . are of great interest as more than presentations of theoretical physics: They are a monument to a remarkable community of creative physicists who managed to flourish intellectually, under conditions that were materially difficult and cognitively surreal, during the declining years of the Soviet Union. Shifman was at the center of the ITEP group, intellectual descendants of Lev Landau and Isaac Pomeranchuk, which made major contributions to high energy theory. (This was recognized, for example, by the APS's 1999 Sakurai Prize, which was awarded jointly to Shifman, Arkady Vainshtein, and Valentine Zakharov). In a charming introduction, Shifman describes some aspects of the way the group functioned. He gives a sense of the joy the members managed to find in their work--and in each other--in an often sinister and sometimes hostile environment.

The bulk of the book is a series of short monographs that grew out of research-oriented courses given as part of a regular tradition at ITEP. The range of topics, within high energy theory, is quite diverse. It includes heavy quark physics, quantum chromodynamics sum rules (also called ITEP or SVZ--for Shifman, Vainshtein, Zakharov--sum rules), instantons, conformal field theory, supersymmetric quantum mechanics, and supersymmetric quantum field theory. There is also a final course on a fascinating but comparatively sparsely studied (and at present rather isolated) chapter of mathematical physics--what Shifman calls quasi-exactly solvable models. In these models some, but not all, of the low-energy states and their wavefunctions can be found algebraically.

The treatment of each topic is clear and rigorous, expounded in vigorous prose and leavened from time to time with strong opinions frankly expressed. They put me in mind of Sidney Coleman's legendary series of Erice lectures, *Aspects of Symmetry* (Cambridge, 1988). Exalted company, indeed!

The common thread that ties most of these courses together is Shifman's expressed desire to do justice to "quantum chromodynamics, *the* theory of our world." The first two courses, on heavy quarks and sum rules, present approximation techniques that are firmly rooted in the microscopic theory and can be applied to describe specific experimental situations in a detailed quantitative fashion, as Shifman discusses. The third, on instantons (in the QCD context), discusses an aspect of QCD that is quite fundamental--without its instantons, QCD would possess symmetries that are not observed in nature--but not part of any controlled approximation. In the later courses, the emphasis shifts from approximate results in real QCD to exact results for (one would hope) instructive models.

Shifman expresses his philosophy in a striking passage (one of many):

As time passes, the hope that the full analytic solution of QCD will be found, fades away. . . . theorists whose philosophy is 'all or nothing' abandoned the field. [The 'all or nothing' philosophy is widespread and, unfortunately, not only in theoretical physics. This is a favorite child of the so-called revolutionaries in all times and in all countries. The misfortunes it brought to our world are innumerable.] (In the original, the material in brackets is a footnote.)

In light of this comment, it is somewhat ironic that he puts so much emphasis on exact results for unrealistic models featuring supersymmetry and/or conformal symmetry. For these have made, in practice, extremely little impact on the application of QCD to the physical world. As Shifman concludes, somewhat ruefully: "It remains to be seen whether the remarkable discoveries and the elegant, powerful methods . . . will prove to be helpful in solving the messy problems of real-life particle physics."

However, woefully underplayed here are such tangibly significant developments as:

- Ever more sophisticated factorization methods, better algorithms, and gritty calculations that have sculpted perturbative QCD into a versatile and indispensable tool for the analysis and design of accelerator experiments;

- Numerical work using lattice QCD that has proved the fundamental nonperturbative results (confinement, chiral symmetry breaking) directly, given good quantitative results for the low-energy spectrum, and produced many impressive results for heavy-quark systems;

- Weak-coupling but nonperturbative methods that have been used to describe the high-density phase in a controlled approximation, with confinement and chiral symmetry breaking as demonstrable, analytic

consequences; and

- The high-temperature frontier (also partially accessible to weak coupling methods) now being explored in heavy ion collisions.

The material Shifman presents on supersymmetry and conformal symmetry is potentially of great interest in connection with attempts to describe particle physics beyond the Standard Model, critical and other condensed-matter phenomena, and string/M theory. In view of their extraordinary virtues, mentioned above, I can enthusiastically recommend Shifman's monographs as essential supplementary reading for any of the topics they touch. But don't expect a balanced description of QCD.

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Table of Contents About Physics Today Contact us