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SUBAL DAS GUPTA
McGill University
Montreal, Quebec, Canada
GARY D. WESTFALL
Michigan State University
9/93 *East Lansing, Michigan*

Two Laser Pioneers' Early Affiliation

My article "*Physical Review* Records the Birth of the Laser Era" (October, page 28) mentions the current affiliations of Arthur Schawlow and Ali Javan in the text on page 30 and in the figure caption on page 31. At the time of their early laser work, both Schawlow and Javan were affiliated with Bell Telephone Laboratories.

NICOLAAS BLOEMBERGEN
Harvard University
11/93 *Cambridge, Massachusetts*

Complexity Study: An Alternative History

Philip W. Anderson's Reference Frame columns on "complexity" (July 1991, page 9; June 1992, page 9) are establishing and fixing a history of complexity study, and its relation to the Santa Fe Institute, in the physics community. This letter offers an alternative view on the history of such study. Even though Anderson asserted to me a decade and a half ago that the studies made by my colleagues and me should not strictly be considered physics but rather a scientific extension beyond or perhaps peripheral to physics, I believe members of the physics community should have the opportunity to learn about our contributions to a physical foundation for complex systems and to judge them if they so choose.

Those efforts began in the 1940s at the National Bureau of Standards in cross-disciplinary studies, of interest to government and industry, related to a variety of flow field and solid-state material problems within instrumentation and metrology and to the biophysics of high-altitude flight. They expanded with continuing systems studies in physiological physics and hydrodynamics in the 1950s and involvement in the organization of interdisciplinary sessions for the system regulation and control interests in the engineering societies from the 1950s on. Salient inspiration for such engineering physics studies came from APS's mixed-discipline sponsorship of a 1939 temperature symposium, technical needs evolving in World War II, graduate study with George Gamow, and Edward U. Condon's making two issues of *Reviews of Modern Physics* available to a biophysical study program in 1952. A biological systems group that I started in the 1960s led to a systems science group among colleagues for whom I consulted at the University of Southern California in the 1970s and transformed into a complex systems group at the University of California, Los Angeles, when I moved there in the 1980s. A further extension in the 1970s into social science study has been conducted since the 1980s with a unified, physically oriented social science study group.

Branching from the relatively simpler studies of the engineering physics of fluids (laminar and turbulent flow), these studies—always hierarchical—opened up to the complexity of biological and social physical systems, invariably dynamical, developmental and evolutionary. Technically, they are fluid–plastic–elastic systems composed of units (atomistic components) whose internal processes involve very long time delays and attendant memory function as compared with external interaction time scales between units. Descriptively, we identify them as (or as found in) nature, life, humankind, mind and society.

The general themes common to all these complex systems studies go by the name "homeokinetics" (formally originated in 1965; see, for example, references 2, 5 and 12); they include a set of general principles that apply to complex systems of all types and a set of strategies for studying, describing and analyzing such systems. Homeokinetic strategies are usefully applied to systems too complex to be treated by formal mathematical modeling. Such applications consist mainly of deducing or intelligently guessing from extensive physical background and data the fundamental processes by which the particular system operates at its many and varied temporal and spatial scales and of understanding the interactions among those processes.

Because our studies generally do not fall into standard disciplinary categories and because they generally contain a minimum of formal mathematical modeling (commonly, just a few essential abstracted ideas), they are usually neither written for nor accepted by standard academic disciplinary journals. Our more than 200 papers, reports and book chapters are thus scattered in many journals, books and government publications. By editorial limitation, I am here allowed to list only about a dozen references. A more complete listing is available on request.

References 1–4 cover biophysical studies. Reference 1, for example, describes the physical–hydrodynamic design of mammals; reference 3 discusses geological–biological evolution. References 5–8 are in the social sciences. Reference 5, for example, presents a description of social operation along combined anthropological and physical lines; reference 7 compares a Marxist and positivist picture of social operation with a physical picture. References 9–12 relate to systems physics, beginning from hydrodynamic flow in tubes and proceeding to general principles and on to self-organization of rivers and societies. Reference 13 offers an interdisciplinary unification of social and biological evolution with Earth's geophysical processes, both internal and external.

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ARTHUR S. IBERALL
5070 Avenida del Sol
3/93 *Laguna Hills, CA 92653-1876*

ANDERSON REPLIES: My Reference Frame column of June 1992 was not at all meant to imply that the Santa Fe Institute either originated complex systems studies or had a monopoly on them. Many previous groups have contributed useful ideas, and many groups work throughout the world in this field. In addition to Arthur Iberall's associates, the "Michigan Mafia" group founded by Walter Reit; the pioneers of artificial intelligence such as Marvin Minsky; Iberall's own teacher Walter McCulloch; Dave Marr and other neural network pioneers; researchers in the extensive field of origin-of-life studies, including Alan Turing, Hans Kuhn, Manfred Eigen and Leslie Orgel; and many others have contributed to the field.

A Reference Frame column is not a review article and need not have any bibliography, much less a complete one. Mine would have included, if it existed, all of the above and more. SFI claims only that it draws together and focuses an extraordinary number of these threads; that wherever possible we draw on people who have contributed solidly in their own fields and on ideas with proven track records; and that we can see, more or less vaguely, certain "integrative themes" (the title of a forthcoming SFI book) emerging.

I freely acknowledge my debt to "Ibby" Iberall, who, with his friend Gene Yates, shared with me their fantastic breadth of knowledge of complex systems from the universe to the cell. Gene and Ibby also introduced me to many of the actors in this world, specifically at a wonderful conference they organized in Dubrovnik in 1980. But even my own background already included the spin glass (in which many simple interacting agents give rise to complex behavior), and my article "More Is Different" dates from 1967.

I am of course glad that Ibby has given us this thumbnail sketch of his ideas. There is much in them that is worth thinking about.

PHILIP W. ANDERSON
Princeton University
11/93 *Princeton, New Jersey*

Might DNA Shape Tell Proteins How to Fold?

I was fascinated by the well-written article by Hue Sun Chan and Ken A. Dill on the folding structure of globular proteins (February 1993, page 24). The scientific uncertainties expressed in the article are a pleasant departure from the rigid structure of semiconductor physics, with which I was concerned in my career.

I was particularly intrigued by