Applications of Chaos, which was sponsored by the Electric Power Research Institute and held in San Francisco in December 1990. The aim of the workshop was to explore existing and potential applications of chaos, particularly in engineering, physics, and chemistry.

The book contains 20 chapters divided into five parts: chaos in engineering and technological applications; applications in the physical sciences; applications in the physiological sciences; chaotic time series and forecasting; and general topics. Almost all of the authors are well known to the chaos community. The volume concludes with a discussion of the various articles by the workshop participants.

The articles and discussion illustrate three important points about using the concepts of chaos. These are of special concern to engineers who deal with parameter control problems: the need to avoid chaotic basins of attraction; the need to be in chaotic basins of attraction; and the importance of analyzing transient behavior. While most physicists and engineers would anticipate the importance of the first point, many might not anticipate the importance of the latter two.

The fatigue of cables due to chaotic flexing, the dynamic instability of ships in chaotic waves and the chaotic fluctuations of large transport belts are examples of the need to avoid chaotic basins of attraction. Chaotic mixing for heat transfer enhancement and in chemical reactions, and the removal of impurities using chaos-enhanced convection are examples of the need to be in chaotic basins of attraction. Many engineering problems—transport belts, dynamical stability of ships at sea, atmospheric flight dynamics and the forecasting of catastrophes—reflect the need to pay close attention to transient behavior.

Two chapters indicate considerable potential for using chaotic concepts in electrocardiography and physiology. It is interesting that a persuasive case can be made for the presence of subtle arrhythmias in the heart beats of healthy animals and that disease can sometimes be characterized as "decomplexification." Other articles in the book are more methodological and will interest a very wide audience. For example, one deals with the nonlinear modelling of noisy chaotic time series, and another is on forecasting catastrophes by exploiting chaotic dynamics.

The articles are for the most part well written and easily understood, and in most cases they provide fascinating examples of actual or realistically implementable applications of the concepts of chaos. This book will be warmly received by the scientific community and by engineers who are interested in the applications of new scientific ideas.

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Local Quantum Physics: Fields, Particles, Algebras

Rudolf Haag
Springer-Verlag, New York, 1992. 356 pp. $59.00 hc
ISBN 0-387-53610-8

This superb book, appropriately dedicated to three "grand masters" of the previous generation—Eugene Wigner, and the late Valja Bargmann and Res Jost—aptly summarizes Rudolf Haag's fundamental contributions to the understanding of quantum field theory. If one wants to characterize either the work or the book in four words, they are "common sense mathematical physics." Indeed, both the expert in the field and the novice will enjoy Haag's insightful exposition of the basic physics behind the abstract mathematics, and his unique way of making complicated mathematical theorems plausible without getting bogged down in tedious details.

Technically, the book is nicely presented. I particularly appreciated the combined author index and references, which refer back to the chapter and section in which the work is cited. Unfortunately the book contains a large number of typos and misspellings, which a good copy editor should have caught. There is also a lack of consistency between British and US spellings and an unorthodox placement of commas. But these tiny flaws in no way detract from the value of the book, which should be in every serious theorist's library.

The book starts out with a masterful overview of quantum mechanics, the principle of locality, Poincaré invariance, the action principle, and "basic quantum field theory." Worth mentioning are an illuminating discussion of the fundamentals of quantum mechanics (leading naturally to the need for an algebraic treatment) and a very clear definition of states as positive linear functionals on the algebras of observables. Though this chapter covers traditional material, it contains many insights not found in other books.

Chapter II takes us (in about 50 pages) from Haag's theorem on the unitary non-equivalence of free and interacting field theories, through Wightman's axioms for quantum field theory, covariant perturbation theory and a smattering of "constructive field theory" to Haag's original contributions to the understanding of the particle picture and to the Haag–Ruelle scattering theory. Again, the reader will enjoy the physical insight behind the mathematical formalism. Chapter III is devoted to a discussion of C^* algebras and von Neumann algebras in the context of quantum field theory. The proposal to base the theory on a net (a generalization of a sequence, with a "continuous label") of local algebras corresponding to different space–time regions originated in Haag's contribution to the 1957 Lille Conference. He suggested that the algebras should be generated by both observable and unobservable fields and taken as operator algebras acting on Hilbert space. This led to a deeper understanding of collision theory by eliminating the distinction between elementary and composite particles and basic fields. Huzihiro Araki helped to develop the theory in terms of nets of von Neumann algebras of observables. The idea that one should take an abstract C^* algebra as the basic object and that its specific representation is irrelevant to physics was advocated by Irving Segal in 1947 and again at the 1957 conference. However, it took several years until Haag and Daniel Kastler realized that a *net* of (abstract) C^* algebras of observables, associated with regions of spacetime, provided the natural setting for understanding superselection rules and the role of unobservable fields. These issues are discussed in the book.

The analysis of superselection sectors put forth by Sergio Doplicher, Haag and John Roberts, and its extension by Detlev Buchholz and Klaus Fredenhagen to topological charges which possibly occur in massive gauge theories, is described in detail in chapter IV. It consists of a derivation of the superselection structure of quantum field theory essentially from the Haag–Kastler axioms. The remarkable result of this analysis is that from very few assumptions one can deduce results such as the existence of the Bose–Fermi alternative and of unobservable fields, as well as the equivalence of parastatistics with the existence of a unitary group of internal symmetries (at least for theories of massive particles). It is strange that until fairly recently these deep results were not generally known by particle theorists. In this chapter, as before, the author manages to keep the important physics in the foreground, while using high-powered mathematical concepts from category theory. The chapter ends with a brief mention of recent results on braid group statistics in low dimensions.

Chapter V is devoted to a description of thermal states and modular automorphisms. As a characterization of equilibrium states in the statistical mechanics of infinite systems, Haag, Nico Hugenholtz and Marinus Winnink have adopted the KMS condition (named for Ryogo Kubo, Paul Martin and Julian Schwinger), which extends the properties of analyticity (and periodicity) of thermal Green's functions in a strip of width $i\beta = i/kT$ in the complex time plane. Here again, developments in physics and in mathematics—the discovery of the "modular automorphisms" of von Neumann algebras by Minoru Tomita and Masamichi Takesaki—took place along remarkably parallel, independent paths. This theory has ultimately led to profound mathematical results by Alain Connes on the classification of factors and to Vaughan Jones's beautiful results in knot theory. Modular invariance has applications not only in statistical physics, but also in describing quantum fields localized in a wedge and in extensions to conformal field theory.

Chapter VI starts with a deep analysis of what it means to detect particles and describe collisions, and the trial and error involved in designing experimental detectors and good theories. Haag again provides deep insights for understanding real physics in these very abstract terms. The discussion moves on to asymptotic particle configurations and to Buchholz's recent analysis of the particle content of the quantum field algebraic theory. The chapter ends with a brief discussion of the concepts of particle and infraparticle, relating the C* algebra approach to actual interpretation of scattering experiments.

Chapter VII, Retrospective and Outlook, starts with a comparison of the relative merits of the algebraic approach and constructive field theory. After pointing out the virtues and beauty of the algebraic approach, Haag admits that so far "it has given a frame and a language not a theory... There are few quantitative consequencies which are independent of a specific model." He goes on to list the strengths and weaknesses of Feynman path integrals in the Euclidean domain. Again the reader will be impressed by Haag's uncanny ability to get to the essence of the problem. Haag ends by noting that, "It may be considered as the central challenge to the algebraic approach to incorporate the local gauge principle into its conceptual frame." He admits that the combination of differential geometric ideas with the net structure of local algebras (an old dream of this reviewer) is in its infancy. Haag hints at the relationship of nets of local algebras with general relativity (which is briefly touched in the last section of the chapter), and he concludes by mentioning the need for synthesizing the Lagrangian and algebraic approaches. After a brief mention of supersymmetry in section 3, Haag summarizes his work with Klaus Fredenhagen and Heide Narnhofer on quantum field theory in a curved background and derives Hawking radiation from the algebraic formulation.

It is comforting to read a book that touches the forefront of theoretical physics research and at the same time is certain not to be dated when the next fashion in theoretical physics makes its appearance. The framework discussed by Haag (and to which he devoted a half-century of work) is one against which most future developments in this field will have to be tested. This book is bound to occupy a place on a par with other classics in the mathematical physics literature.

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Chaos and Nonlinear Systems

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