the theory and data that have accumulated since Piaget on the growth of cognitive skills and conceptual understanding early in human development. Cognitive competences more systematic than was previously expected have been found in young children in such domains of knowledge and skill as first language proficiency, general spatial knowledge and related perceptual abilities, elementary concepts of number, causal thinking, and classification. The proficiencies involved appear to be acquired on the basis of interaction between the increasing organization of knowledge and the kinds of cognitive processes described in Sternberg's componential theory.

Beyond IQ is a challenge to further experiment and theory. It also gives evidence that the scientific study of intelligence has moved beyond the stage of measuring undefined entities to a stage of investigating cognitive abilities so that intellectual proficiency can be understood and enhanced.

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A System of Academies

Science Reorganized. Scientific Societies in the Eighteenth Century. JAMES E. MCCLELLAN III. Columbia University Press, New York, 1985. xxxii, 413 pp., illus. $45.

Scientific societies were the leading institutions supporting natural philosophy in the 17th and 18th centuries. They united natural philosophers in common endeavor, disseminated research through correspondence and the first scientific journals, and provided limited support for research in the form of salaries, laboratories, and access to state scientific employment. They have been celebrated since their earliest foundation by historians, who, however, have generally focused on 17th-century institutions or on the history of individual academies. McClellan's *Science Reorganized: Scientific Societies in the Eighteenth Century* is, to my knowledge, the first monograph to offer a comprehensive survey of the scientific societies during the century of their greatest significance.

McClellan covers all the more important societies and numerous lesser ones, giving a brief history of each and noting its sources of support, internal organization, publications, physical plant, sponsorship of prize competitions, and other activities. In the course of this survey he rightly traces what he calls a "scientific society movement" (p. 41), in which the numbers of societies grew exponentially. McClellan divides this movement into three periods. The Royal Society of London and the Académie Royale des Sciences at Paris were the only significant and permanent foundations prior to 1700. After 1700 the movement "began to pick up steam" (p. 67), and by 1750 all the major European academies were founded—those at Berlin, St. Petersburg, Stockholm, and Bologna and in several of the French provinces. The last period, 1750–1790, enjoyed "the full flowering of the scientific society system" (p. 68), including several attempts at unification among societies. By the late 18th century every European state either possessed an academy or had felt the stirrings of the movement. The entire system collapsed, however, in the chaos of the French revolutionary era; when they revived after the Restoration, the academies faced tough competition from universities and specialized scientific societies. The "age of academies" had ended.

Except for two chapters on the international relations among societies, McClellan does not base his account on original research. But he has gathered information on a very large subject and systematized it in a useful way. A taxonomy of scientific societies in the first chapter sets forth distinctions regarding modes of patronage, organization, and activities, and two appendixes list all the academies with relevant information in summary form. The narrative sections of the book, the appendixes, and a substantial bibliography offer an excellent overview of the scientific societies of the 18th century.

The book is less strong in its conclusions. Having established the strength of the scientific society movement, McClellan emphasizes that it "was a real thing" (pp. 54, 68). On the other hand he overstates his case in claiming that the movement's importance was "equaled only perhaps by the emergence of medieval universities in the twelfth and thirteenth centuries" (p. 140). Such a conclusion requires some evaluation of the societies' contributions to the institutionalization and content of science; but McClellan has here laid out only the parameters of their existence. Likewise overstated is the argument for an international network of cooperating institutions, for which McClellan offers as evidence little more than their exchange of correspondence and publications. McClellan makes too much of their coordination and exchange of observations on the occasions of several well-known astronomical and geodesic expeditions—those to Lapland and Peru in 1735 and to observe the transits of Venus in 1761 and 1769. Far from being triumphs of international cooperation, these expeditions were nationalistic undertakings.

Several lines of investigation might have led to more substantial conclusions than are offered here. Comparisons might be drawn among the academies in such respects as size, sources of support, and organization and the results set in the larger history of the Enlightenment. A study of prize competitions, the importance of which McClellan recognizes, would establish the extent of their influence on research. Finally, English usage could be much improved, in particular, the use of "cartology" in preference to "cartography" (p. 119 and passim). Attention to any of these matters would have substantially increased the value of this work.

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Gauge Theories

Progress in Gauge Field Theory. G. 'T HOOFT, A. JAFFE, H. LEHMANN, P. K. MITTER, I. M. SINGER, and R. STORA, Eds. Plenum, New York, 1984. x, 608 pp., illus. $89.50. NATO ASI Series B, vol. 115. From an institute, Cargèse, Corsica, France, Sept. 1983.

Gauge theories have dominated theoretical elementary particle physics for the last 15 years, and they have played an important role in other fields of theoretical and mathematical physics. Based on the "gauge principle" of invariance of physical laws under local symmetry transformations, which first appeared in 1918 in H. Weyl's almost-forgotten attempt to unify electromagnetism with gravity and was generalized to non-Abelian symmetry groups by Yang and Mills in 1954, gauge theories have been the key to the successful unification of weak and electromagnetic forces as well as to the generally accepted description of strong interactions by quantum chromodynamics (QCD) and a large number of attempts to further unify the electroweak and strong forces in a so-called grand unified theory (GUT).

Lately, however, there are signs that the era of the dominance of gauge theories may be over and that the so-called

superstring theories may take over the dominant role. So this might be an unfortunate time to draw attention to a book on gauge theories that is composed of lectures given two years ago. But it should be kept in mind that even if the prophecies concerning string theories turn out to be correct that will not make the study of gauge theories irrelevant—just as the advent of quantum mechanics has not made the study of classical dynamical systems irrelevant.

Progress in Gauge Field Theory offers an overview of the many aspects of gauge theories that is still useful today. The material can be grouped into three partly overlapping categories: classical gauge field theories, lattice gauge theories, and the renormalization group. In addition there are papers by Fröhlich and 't Hooft that do not quite fit into any of these categories.

The subject of classical gauge theories has blossomed in the last decade. It is one of the main areas of contact between mathematics and physics, as a paper by C. Taubes on the connection between Morse theory and gauge fields exemplifies.

Papers by Alvarez-Gaumé and by Stora on anomalies mark the transition from classical to quantized theory. Anomalies are a phenomenon of quantum field theory; they are extra terms containing Planck's constant as a factor that have to be added to the classical conservation laws. Nevertheless their form is determined by classical (cohomological) considerations.

With the subject of lattice gauge theory one is fully in the quantum world as determined by the (Euclidean) "sum over histories." To make this structure mathematically sensible, space-time is approximated rather brutally by a lattice. Thereby one gains one important advantage: quantum field theory is reduced to quadratures, which means that everything can in principle be computed by carrying out a large number of integrations.

The "Monte Carlo industry" tries to evaluate the necessary integrals numerically by a stochastic algorithm. It produces results that can be directly compared with experiment. A paper by B. Berg is an excellent survey of the calculation of particle ("glueball") masses by this method; it explains both the conceptual background and the techniques of computation. One of the virtues of the paper is that it does not try to mask the difficulties and uncertainties inherent in this game.

Lattice gauge theories can of course also be analyzed nonnumerically, and many interesting results have been obtained by applying the tools of statistical mechanics. There are also problems that are specific to the lattice, particularly if one includes fermions. A paper by Göckeler and Joos that might become a standard reference on the subject presents a very clear and complete account of one solution to these problems.

The volume contains many interesting contributions on various other problems of lattice gauge theories. Papers by Lüscher and by Parisi are particularly original. The first points out a surprising relation between scattering amplitudes and finite size effects, and the second proposes improvements in the stochastic algorithms that have since been applied with promising results.

The lattice cutoff is, of course, supposed to be removed in the end. This is a highly nontrivial problem, and there is universal agreement that its solution will have to make use of the renormalization group à la Wilson and Kadanoff to study the flow of the effective interactions under a systematic elimination of the short wavelength modes.

Wilson himself gives an account of a recent innovation, the so-called "Monte Carlo renormalization group," which uses numerical methods to study the renormalization group flow.

The other papers in the book on the renormalization group are rigorously mathematical. Two papers by Gawędzki and Kupiainen give a glimpse of their work applying the renormalization group to the study of critical phenomena and to the construction of continuum quantum field theories (of the nongauge kind). A contribution by Balaban *et al.* gives a glimpse of another big enterprise that utilizes Wilson's ideas about the renormalization group for the construction of continuum quantum gauge theories. Both subjects have evolved considerably since 1983, and the actual work is too complicated to be described satisfactorily in such short papers. But the papers are useful guides to the ideas and to the literature.

Fröhlich presents in a coherent fashion a subset of his work (with collaborators) of recent years. The paper deals with random geometric objects like walks and surfaces and has led to important results in "ordinary" field theories (triviality of ϕ^4); its analysis of random surfaces also has shed new light on the basic physical problems of gauge theories, such as quark confinement. This last subject also touches upon the string theories that are so popular today. Fröhlich's contribution is self-contained and detailed enough to be understood without burying oneself in the original literature.

Finally 't Hooft gives an account of his work on "planar field theories" including the proof of Borel summability of planar ϕ^4. This is a tough and serious paper that does not spare the reader technical details. Though most of the work discussed in the paper has been published in original articles, the version given here may be more accessible.

On the whole the book contains a good cross section of the ideas and methods used in gauge theories and related fields. One approach that does not appear is the so-called stochastic quantization proposed by Parisi and Wu and further developed by Zwanziger and others, but it cannot be the purpose of such a book to cover everything. After two years the book remains fresh and useful for somebody who has some general knowledge of gauge theories and wants to penetrate deeper into the subject. It is particularly useful as a guide to the original literature. It belongs in any serious theoretical physics library.

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