earlier hypotheses. Simple hourglass timers may be the main or sole mediators of photoperiodism in some plants, certain insects, and a lizard (*Anolis carolinensis*). On the other hand, a particular phase in the circadian cycle may coincide with light only when the photoperiod reaches a critical value (external coincidence; a more explicit version of Bünning's hypothesis), or changes in photoperiod may produce changes in the phase relations among two or more endogenous circadian oscillations (internal coincidence). A substantial portion of the book is devoted to the formal analysis of circadian rhythms and their role in photoperiodism.

One cannot fail to be impressed by the ever-increasing sophistication of models based on oscillator theory and the proliferation of experimental designs now widely used to test predictions derived from such models. In addition to traditional resonance experiments (in which light signals are omitted for multiples of 24 hours), single-pulse perturbations (for example, to map phase response curves), T cycles (entrainment by one light pulse per cycle), and symmetrical and asymmetrical skeleton photoperiods (two light pulses per cycle) have become standard tools for probing the functional properties of the circadian system as well as its mediation of the photoperiodic response.

The opening chapter (by C. S. Pittendrigh) provides an elegant modern version of the circadian system, involving a system pacemaker and coupled slave oscillators. Though the model evolved primarily from data on the *Drosophila* emergence rhythm, its basic features have general applicability. The important feature of the model with regard to seasonal reproduction is the inevitable change in phase relations among coupled oscillators as the photoperiod changes. Thus, the modus operandi for internal coincidence exists in any organism with more than one circadian pacemaker.

Whereas for mammals the evidence increasingly seems to favor internal coincidence, strong evidence for external coincidence (with a little help from an hourglass) is presented for insects. Of course, such mechanisms need not be mutually exclusive. Two chapters present evidence for a complementary system, a thermoperiodic response with formal properties quite similar to photoperiodism in certain insects. The possible existence of a circannual clock, which is not simply based on frequency demultiplication of circadian oscillations, is indicated by the testicular response of starlings and garden warblers.

Progress in elucidating the physiological bases of photoperiodism and circadian rhythmicity has been much slower. Nevertheless, there is increasing interest in physiological variables, ranging from plant enzymes to patterns of gonadotropin secretion in quail, hamsters, and sheep. Attempts to localize and study circadian pacemakers both in vivo and in vitro are also reviewed. The complex role of the pineal gland in the mediation of circadian rhythms and in photoperiodism is discussed in several chapters. The effects of pinealectomy (and of lesions of the suprachiasmatic nucleus) seem to vary considerably from species to species, and, given the number of suspected circadian oscillators in insects, one wonders (with Aschoff, who presented the Annual Colston Lecture, the text of which concludes the volume) how many "clocks" have yet to be discovered in vertebrates.

Overall, the main virtue of the book is that it conveys the variety and diversity of mechanisms used by organisms to regulate seasonal reproduction. Although much of the information presented here can be found in other sources, it is of great value to have it all in one place. This book serves as a handy reference for anyone interested in seasonal reproduction and offers much to those with more than a passing interest in biological rhythms in general.

FRIEDRICH K. STEPHAN
*Department of Psychology,*
*Florida State University,*
*Tallahassee 32306*

## Elementary Particle Physics

**To Fulfill a Vision.** Proceedings of a symposium, Jerusalem, March 1979. YUVAL NE'EMAN, Ed. Addison-Wesley Advanced Book Program, Reading, Mass., 1981. xxxiv, 280 pp. $39.50.

This volume, the proceedings of half of the Jerusalem Einstein Centennial Symposium, is a companion volume to the proceedings of the Princeton Einstein Centennial Symposium, published as *Some Strangeness in the Proportion* (Harry Woolf, Ed., Addison-Wesley, 1980). The proceedings of the other half of the Jerusalem symposium, published as *Albert Einstein: Historical and Cultural Perspectives* (G. Holton and Y. Elkana, Eds., Princeton Univ. Press, 1982), covers the historic impact of Einstein's ideas in politics and international security, philosophy and linguistics, art, and psychoanalysis and sociology. Together the three volumes present the best-informed and most compact review of Einstein's impact to emerge so far out of his centenary year.

The volume reviewed here contains short summaries of the current situation in quantum chromodynamics (QCD) by Y. Nambu, G. 't Hooft, R. Dashen, and H. J. Lipkin and in quantum flavor dynamics (QFD) by S. L. Glashow, H. Harari, and R. Gatto. There are long reviews of the program for grand unification of electroweak and strong interactions (GUT's) by S. Weinberg and J. C. Pati and of supergravity by D. Z. Freedman. These are all excellent, generally nontechnical reviews by authors who helped to create and continue to be at the center of activity in QCD, QFD, and GUT's.

The two most promising possibilities for completing the theoretical structure of fundamental particle physics are GUT's and supergravity. GUT's neglect gravity and aim to unify QCD, the unbroken symmetry of strong interactions, and QFD, the broken symmetry of electroweak interactions. The theoretical possibilities are so constrained that only three separate local gauge theories are possible: spin 1 gauge particles (electrodynamics and its non-Abelian generalization, Yang-Mills theories), spin 2 gauge particles (general relativity), and spin 3/2 gauge particles (supergravity). Supergravity is the gauge theory of local supersymmetry transformations connecting bosons and fermions. Freedman shows how supergravity incorporates Einstein's three precepts: symmetry of physical laws (supergravity is the only known invariance compatible with quantum field theory that unifies spin and internal symmetry); geometrization of physics (the four-dimensional space-time geometry is extended to a superspace parameterized by four Bose coordinates and four anticommuting Fermi coordinates); and unification (gravitation can be unified with the other two gauge interactions only via a spin 3/2 gauge particle, the gravitino). Y. Ne'eman reviews work on affine or Poincaré gauge theories.

These papers are masterly summaries of the present situation in the rapidly developing areas of QCD, QFD, GUT's, and supergravity. Of more permanent value are papers by C. N. Yang, P. G. Bergmann, and F. Gürsey on unified field theories and the geometrization of physics. Einstein's pursuit of unification of gravity and electrodynamics was motivated by his search for nonsingular solutions to the field equations, by his wish to explain the spectrum of particles and interactions, and by his search for a

deterministic theory in place of quantum mechanics. Nowadays, however, theorists benefit by good contact with the phenomenology of strong and weak interactions and the field theories are inherently quantum field theories.

Yang points out that geometrization is only a heuristic device for expressing unification. The gauge theories that have already unified electromagnetic and weak interactions and promise to incorporate strong and gravitational interactions are all quantum generalizations of fiber bundles that necessarily incorporate topological complexity. This is the direction in which, while his search for a deterministic theory is being abandoned, Einstein's Riemannian geometry is now being generalized so as to incorporate all interactions.

Bergmann discusses unified field theories under three classifications: those that maintain usual four-dimensional space-time but generalize the Riemannian geometry so as to accommodate a greater variety of physical fields, those that increase the space-time dimensionality, and those that complexify space-time. Penrose twistors and supergravity both fall in the last category. Because spinors appear only in quantum mechanics, supergravity is an inherently quantum field theory.

Gürsey points out that Einstein's failure to unify actually signaled the beginning of a new level of geometrization of contemporary relativistic physics. He is especially good at translating Einstein's program into modern terms. In fact, the papers by Gürsey, Bergmann, and Yang will be invaluable to historians of contemporary physics.

At the intersection of gravitation and quantum theory, J. D. Beckenstein contributes a beautiful exposition of black hole statistical physics. N. Rosen writes on Mach's principle, which was heuristically important to Einstein in his development of general relativity. Because anti-Mach (deSitter) cosmologies are now known in which geometry is fixed by a pure gravitational field without the presence of matter, Mach's principle is now mostly of historical interest. It may be used to select physically admissible solutions of Einstein's field equations. Einstein and Wheeler have, at different times, argued that Mach's principle requires that the universe be closed since only in that case is the solution of the field equations determined only by the matter-energy tensor. It remains to be seen whether our universe is closed and, if so, whether this justifies any interpretation of Mach's principle.

The editor allows his own opinions and contributions to intrude in every section of the book. (Though omitting any details concerning or precise reference to the proceedings of the other half of the Jerusalem symposium, the editor incorporates in the present volume two previously published articles of his own.) This annoying practice detracts from the special and high quality of all the other thoughtful and distinguished contributions to the volume.

S. A. BLUDMAN
*Department of Physics, University of Pennsylvania, Philadelphia 19104*

## An Irish Scientist

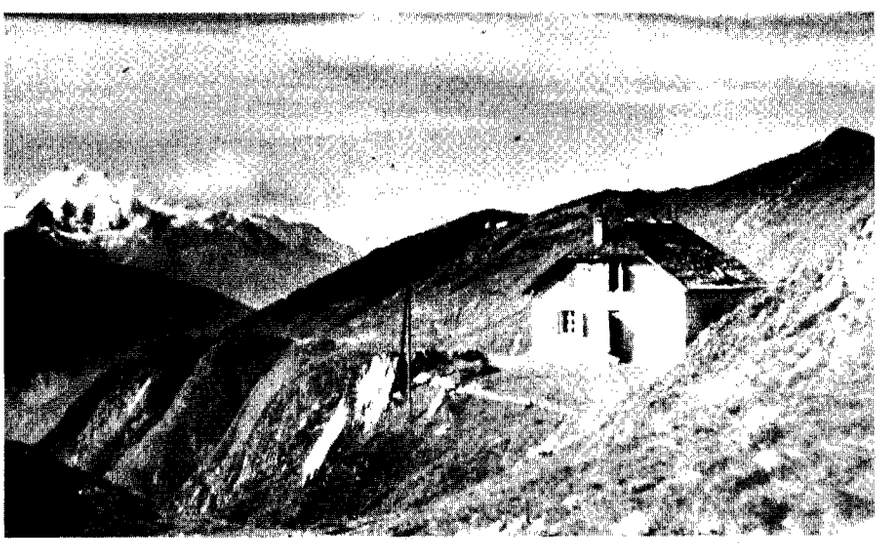
**John Tyndall.** Essays on a Natural Philosopher. W. H. BROCK, N. D. MCMILLAN, and R. C. MOLLAN, Eds. Royal Dublin Society, Dublin, 1981. xii, 220 pp., illus. IR£10. Royal Dublin Society Historical Studies in Irish Science and Technology, no. 3.

Science in Victorian Britain underwent several conceptual and nonconceptual revolutions. The establishment of the chemical atomic theory, the first and second laws of thermodynamics, the electromagnetic theory of light, and the theory of evolution transformed scientific thought. The pursuit of scientific research, largely avocational early in the century, was a full-fledged profession by century's end. The Irish-born John Tyndall (1820–1893), colleague of and successor to Michael Faraday at the Royal Institution in London, lived through the revolutions and especially influenced the ones involving professionalization.

The present book is a kind of homage to Tyndall organized by groups in Ireland mainly interested in awakening local interest in Tyndall. It is the third in a series published by the Royal Dublin Society to "restore the contributions of Irish scientists and technologists to their proper place in the history of the Country." The organizers feel Tyndall has been ignored in Ireland chiefly because of his opposition to Home Rule and his support for the theory of evolution. To correct the situation, they have assembled 16 essays by different contributors on various aspects of Tyndall's career. The result is uneven. Some essays rest on a strong scholarly base. Some tend toward affectionate antiquarianism. Some are brief dips, too limited to illuminate.

One should begin by reading Joe D. Burchfield's "John Tyndall—a biographical sketch" and Frank M. Turner's "John Tyndall and Victorian scientific naturalism." Burchfield has done considerable research for a major study of Tyndall, and Turner has published widely on matters involving Tyndall directly and indirectly. From these two essays emerges the book's deepest understanding of Tyndall.

Tyndall's support for the professionalization of science followed frustrations in the early part of his own career and involved his ever-present, outspoken concern for fairness, as he saw it. In the early 1840's he argued for better treatment of Irishmen like himself working on the English ordnance survey and lost his job. Like many others, he found it neces-



"Tyndall's Alpine summer home at Alp Lusgen over 2100 m. Note the Weisshorn above the roof. Tyndall had great faith in the efficacy of the lightning conductors attached to the chimney pots." Books, papers, maps, and apparatus belonging to Tyndall remained in the house until 1963, when they were acquired from his heirs by E. J. Wiseman. [From *John Tyndall*; courtesy of E. J. Wiseman]