Raven in his summary predicts that plant population biology "will have profound implications for human welfare and survival" we see nothing in the present volume of what these implications might be. There are no sections, for example, on the importance of plant demography for weed control and plant conservation, on the relation of fitness to yield, or on the significance of genetic variation for yield stability. This unfortunate dichotomy within botanical sciences is undoubtedly the result of the exclusion of students of plant populations from funding (except for a recent trickle) by the U.S. Department of Agriculture. Until this is rectified, pure and applied botanical sciences will both be the losers. This volume exposes a real need (reiterated by several contributors) for a multidisciplinary approach to plant population biology. This need has been recognized in Holland, where ambitious team projects are under way, but such efforts remain a pipe dream here.

In the summary, Raven produces a masterly analysis of the current issues and future problems in this field. He warns against coevolutionary studies' becoming stagnant and descriptive; he puzzles why phenotypic plasticity has rarely been investigated with much success; he pleads for more critical studies of selection at the population level, especially with regard to physiological traits; and he still wonders what accounts for the maintenance of those "wide ranging units that we recognize as species." He recognizes that there is "an explosion of experimentation and thought." He talks of new methodologies and how the new population biology is seeking to counter the historical legacy of a "300-year-old encyclopedic mentality which leads us to believe instinctively that it is best to study many kinds of organisms descriptively and relatively superfically rather than a few in depth as systems." In fact I suspect he understates the case, and that we are in the middle of a Kuhnian-type revolution in ecology and evolution, where old methodologies are being replaced by new standards of explanation, new conceptualizations, and new paradigms. It is clear that in the next decade the population biology approach will come to pervade and merge the disciplines of evolutionary biology, physiological ecology, and ecology under a broad umbrella of similar goals and similar experimental methodologies.

JANIS ANTONOVICS
Department of Botany,
Duke University,
Durham, North Carolina 27706

Theoretical Particle Physics

Recent Developments in Gravitation. Proceedings of an institute, Cargèse, Corsica, July 1978. MAURICE LÉVY and S. DESER, Eds. Plenum, New York, 1979. viii, 596 pp. $69.50. NATO Advanced Study Institute Series B, vol. 44.

The last two decades have seen gravitation return to the mainstream of fundamental particle physics because of precise physical observations and important technical and conceptual advances in both general relativity and particle physics. Once the emphasis in general relativity shifted from general coordinate covariance to gauge invariance, general relativity became a paradigm for non-Abelian gauge theories that have been tremendously fruitful in quantum flavor dynamics (weak and electromagnetic interactions) and quantum chromodynamics (strong interactions). The renormalizability of unified electroweak interactions has emboldened particle physicists to attempt a grand unification of electroweak and strong interactions and to look toward an ultimate superunification of all interactions with gravity. Meanwhile, quantum gravity theorists succeeded in renormalizing pure gravity through the one-loop approximation. Although beyond experimental or cosmological test, this limited success with a gauge theory much more difficult than the Yang-Mills theory suggests the promise (and the problems) of supersymmetry and supergravity.

This set of Cargèse lectures begins with reviews of classical general relativity by B. Bertotti, Y. Choquet-Bruhat, and B. Carter. The emphasis here is on the exterior calculus, Lie differentiation on differentiable manifolds, fiber bundles, group structure, and representation theory. A later paper by B. Zumino also contains an excellent treatment of differential geometry, preparatory to a discussion of the geometry of superspace specified by tangent group and torsion constraints. Spinors are useful in gravity theory even when half-integral spins are not present; they are even more natural in supergravity.

In a long section on quantum gravity, D. G. Boulware and L. Parker treat the quantized electromagnetic and charged scalar fields in a background curved space-time using the Schwinger-deWitt proper time formalism, functional integration, Wick rotation, and Riemann normal coordinates. The problem here is to define the vacuum for particles whose wavelength exceeds the space-time curvature: Is the quantum field tied to the geometry (induced polarization) or to radiation propagating independent of geometry? The quantum field theory is renormalizable (by Pauli-Villars regularization, point splitting, or dimensional continuation) because the creation, propagation, and annihilation of particles are all described in tree approximation by local terms. These terms are polynomials in the action and not only are renormalizable but also serve to renormalize the nonlocal terms. The most interesting quantum effect is that general covariance together with local conservation laws requires that the trace of the renormalized energy-momentum tensor be nonvanishing. Parker shows the relation between this trace anomaly and particle creation in asymptotically static Friedman-Robertson-Walker universes.

B. S. DeWitt contrasts the different low- and high-energy properties of Yang-Mills and quantum gravity gauge theories. Yang-Mills theories are renormalizable because they generate only four primitive ultraviolet divergences; although new infrared divergences appear in the coupling of gluons to other massless fields, they can be removed. Their removal appears to be connected with quark confinement and dynamical symmetry breaking in quantum chromodynamics and quantum flavor dynamics. In quantum gravity, no new infrared divergences appear, but the ultraviolet divergences cannot be compensated for beyond the one-loop approximation or in the presence of matter. This is the important difference between Yang-Mills and quantum gravity, although the latter's gauge structure is still not completely unraveled.

The recent developments in supersymmetry and supergravity seem destined to be important to particle physics. As is explained by Zumino, P. Van Nieuwenhuizen, and S. Ferrara, supersymmetry is the graded extension of Poincaré symmetry. This leads to a supergroup whose even and odd (anticommuting) parameters are elements of a Grossmann algebra. The supermultiplets, supersymmetry representations by one-particle states containing both fermions and bosons, have spins 1 and $^1/_2$ in the supersymmetric Yang-Mills case and spins 2 and $^3/_2$ in the simple supergravity case. Even in simple supergravity (only one spinorial charge) these spin $^3/_2$ gravitinos dramatically improve the theory's convergence. In the case of extended supergravity (several spinor charges transforming under some internal symmetry group) the graviton is unified with lower spin fields and gauge invariance is unified with internal symmetry. Supergravity theories are finite through two-loop approximation, which is not the case with ordinary quantum gravity in interaction with matter.

Since only canonical quantization serves as a sure starting point to the path integral formulation and development of Feynman rules for calculation, Deser presents a Hamiltonian formulation of simple supergravity. He discusses the initial value problem and takes the "square root of gravity." Energy is defined in terms of Cauchy data on an initial hypersurface, provided space is asymptotically flat. Following Dirac, one takes the square root of the gravitational energy constraints that are quadratic in the canonical momenta. Deser shows in this way that no tachyons or negative energies can appear in supergravity. Taking the classical limit, he shows that the Einstein equations have only positive energy solutions. If a cosmological constant were included, the global group would be the deSitter group rather than the Poincaré group. Since asymptotic flatness is necessary in order to define the energy, a cosmological constant is thus incompatible with the positive energy theorem. Throughout the book there are many tantalizing statements about the cosmological constant. These are important to particle physics, since particle symmetry breaking or unbreaking necessarily produces a huge vacuum energy density or cosmological constant.

J. Scherk considers supersymmetry in space-time containing extra dimensions of the Bose type. On reducing the number of space-time dimensions to four, these simple supergravity theories become extended supergravity theories.

The reviews so far discussed contain an admirably detailed and clear exposition of the current situation in quantum gravity, supersymmetry, and supergravity. This complete presentation is likely to suggest, as have similar presentations in the past, new pathways in ordinary quantum field theory. Even more suggestive are proposals by S. W. Hawking, G. 't Hooft, and Scherk of ways in which to alter gravity so that it might be fully renormalizable. Hawking uses Euclidean path integrals in order to emphasize topological properties that are essential in getting around the limitations of Feynman diagram perturbations about flat space. He takes the attitude that "quantum theory and indeed the whole of physics is really defined in the Euclidean region and that it is simply a consequence of our perception that we interpret it in the Lorentzian regime." He sums over metrics of very complicated topology in order to see space-time as having "foam like" structure on the Planck length scale. Hawking's lecture also contains an interesting account of black-hole thermodynamics showing that the attractive and long-range nature of gravity permits a microcanonical, but not a canonical, ensemble to be defined: because black holes have negative specific heat, they can be in a box in stable equilibrium with thermal radiation if the total energy is fixed but not if the temperature is fixed.

New physics at the Planck length is also suggested by 't Hooft. At this scale, quantum gauge transformations make the metric tensor scale-dependent. A lattice gauge theory introduced into quantum electrodynamics and quantum chromodynamics formally to simplify calculations is to be taken realistically in quantum gravity.

Because alternative short-distance modifications of the Einstein theory lead to tachyons or ghosts, Scherk suggests the quantized spinning string model for renormalization. This suggestion originates in dual models for elementary particles.

Precisely because of its wealth of technical detail and the problems it exposes, the book is a tribute to how far we have already come in unifying gravitation with the quantum field theory of gauge fields, fermions, and scalar particles, the bread and butter of particle physics. In the conceptual area that mattered to him, the spirit of Einstein triumphs again.

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

Oxygen Biochemistry

Biochemical and Clinical Aspects of Oxygen. Proceedings of a symposium, Fort Collins, Colo., Sept. 1978. WINSLOW S. CAUGHEY, Ed. Academic Press, New York, 1979. xx, 866 pp., illus. $45.

Oxygen plays a fundamental role in the biochemistry of all higher organisms. It is a mixed blessing for the biomolecular machinery of the cell, however; while aerobes have very effectively taken advantage of O_2 as the ultimate electron acceptor in the respiratory chain, they also pay a price for its presence in that they need special safeguards against its indiscriminate action. Both aspects of oxygen biochemistry are well represented in this volume of symposium proceedings. The contents delineate the frontier of current research with contributions ranging from a description of the quantum chemistry of oxygen to a discussion of the role of O_2 in the radiation treatment of tumors. Biochemical studies with an emphasis on physical techniques account for the majority of the papers. The prospective reader should not expect an even, systematic coverage of the important issues but must be prepared to work his or her way through masses of often fascinating yet incidental detail in search of the essential features. Discussions following each paper often help to establish proper perspectives.

The major part of the book is devoted to the molecular machinery and reactions involved in the cell's utilization of oxygen. Heme proteins clearly dominate the scene with 28 contributions out of 51. Other O_2-binding proteins are briefly but competently reviewed, in particular those containing flavin (papers by Massey and by Hemmerich and Wessiak are most noteworthy) or non-heme metal active centers.

The O_2 carriers hemoglobin and myoglobin have been studied more extensively than any other proteins, and they continue to be the focus of new experimental and theoretical endeavors. Iron porphyrin, the prosthetic group of all heme proteins, is a spectroscopist's delight, as is illustrated by excellent contributions on infrared stretching frequencies (Caughey *et al.*), single crystal absorption spectra (Churg *et al.*), and electron paramagnetic resonance and nuclear magnetic resonance studies (Gupta *et al.*). Information gained through these techniques raises new questions about molecular structure and function. Quantum chemical calculations (Goddard and Olafson) provide useful guidelines but need further refinement before they can reproduce the experimental data.

The more complex heme enzymes are represented by papers on peroxidase, cytochrome P450, cytochrome oxidase, and others. Considerable progress has been made in the characterization of membrane-bound proteins such as the mammalian P450's and cytochrome oxidase. Still, much less is known about heme enzymes than about the O_2 carriers; in the absence of structural information the studies focus on the rich chemistry of these proteins, readily monitored by spectroscopic means. Chemical analogs with specified heme ligands have been synthesized to mimic the