that occur in the lowlands, that may have been in demand by highlanders, and that were transportable. J. Marcus documents numerous aspects of Maya agriculture and cultivation practices that can be found in the literature of the colonial period. She concludes that the oldest and most ecologically stable types of cultivation have persisted in the lowlands while the intensive types collapsed, apparently with the Classic civilization (around A.D. 900 to 1000). The implications here are complex. We do not know if the cultural collapse was a product of a subsistence system pushed to its technological limits. Few modern analogies, if any, can be found. Moreover, strong support exists for the thesis that agriculture is largely responsive to demands on production (interacting with other variables); the absence in colonial times of the highly intensive systems may simply reflect the tremendous decline in demand created by the collapse and population reduction some 600 to 700 years before the Spanish conquest. Finally, some intensive systems did persist into colonial times where population concentrations existed, as is demonstrated in the contribution by Friedel and Scarborough.

A comment on Puleston's evaluation of his provocative ramón thesis is a fitting end to this review. Puleston proposed that the concentration of population at the great site of Tikal, Guatemala, could be explained by a major reliance on the harvest of ramón (the fruit of *Brosimum alicastrum*) and its storage in special underground chambers (*chultuns*). Though few researchers doubt that the ancient Maya used ramón, numerous arguments have been raised against the proposition that it was a major staple, including ethnohistoric evidence that it was considered a famine food by the Maya. Most of the direct evidence pertinent to the thesis has been unveiled since Puleston's death. Ecological studies suggest that ramón concentrations around ruins are an edaphic response and that the species shows no signs of genetic manipulation by people. Archival studies have uncovered references to cured maize stored in *chultun*-like features. And recovery of carbonized plant remains from *chultuns* has revealed several foods, but not ramón. However, the legacy of the thesis is not its validity but its inventiveness and the research it stimulated.

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"Splash irrigation (using gourds) of a garlic crop on *tablones* at Aguacatán in highland Guatemala. The *tablones* are raised planting beds separated by ditches, which serve for both drainage and irrigation. Note the pile of crop residue in the foreground, which will be used for fertilizer. October 1974." [Photograph by Kent Mathewson. From W. M. Denevan's paper in *Maya Subsistence*]

A Problem in Unification

Quantum Gravity 2. A Second Oxford Symposium. April 1980. C. J. ISHAM, R. PENROSE, and D. W. SCIAMA, Eds. Clarendon (Oxford University Press), New York, 1981. xiv, 670 pp. $39.95.

Of the fundamental forces (strong, electromagnetic, weak, and gravitational), the one that most steadfastly resists attempts to join it with the others in a unified description is gravity. The failure to include gravity is all the more tantalizing because it means that deep and as yet unexpected connections will be uncovered when unification is achieved. A major impediment to unification is the lack of a completely satisfactory quantum theory of gravity. Recent years have seen a flurry of activity as physicists working in relativity and in particle theory have converged on this key problem. A sampling of the progress made is provided by this Oxford symposium.

The book opens with a clear and remarkably comprehensive survey by Isham of the entire subject of quantum gravity. The other papers are grouped by topic: semiclassical theory, thermodynamics and quantum gravity, cosmology and quantum gravity, quantization of the gravitational field, supergravity, twistors, and other aspects of quantum theory and gravity.

A key guiding factor in the development of unified theories of elementary particle interactions has been renormalizability in flat space-time. (In a renormalizable theory, the infinities can be eliminated by absorbing them into a finite number of observable constants, such as mass and charge, which are then assigned values based on observation.) Because space-time is actually curved the question naturally arises whether a theory that is renormalizable in flat space-time will also be renormalizable in curved space-time.

A fine review by N. D. Birrell addresses the question. The curvature of space-time gives rise to new infinities that depend on the state of the system. Consequently, those infinities cannot be absorbed in the usual way into constants. For a theory to be renormalizable in curved space-time, the state-dependent infinities must almost miraculously cancel one another. Long and difficult calculations have shown that that does indeed occur for certain interacting theories, such as that of a scalar field with quartic self interaction ($\lambda\phi^4$ theory) and (to one loop order) quantum electrodynamics. However, no general theorem has been proved concerning renormalizability in curved space-time, so that such renormalizability may serve to further narrow the class of acceptable theories.

The very consistency of quantum field theory in curved space-time is questioned by M. J. Duff. His main point is that field redefinitions that mix the gravitational field with other fields alter the predictions of curved space-time theories but not of theories in which the gravitational field is also quantized. Duff's criticisms are answered by T. W. B. Kibble and Birrell, who point out, among other things, that the gravitational metric naturally plays a preferred role in curved space-time theories because it is treated as an unquantized classical field. Therefore, it is not surprising that field redefinitions alter the theory. It certainly is not an internal inconsistency of quantum field theory in curved space-time.

Quantum field theory in curved space-time has led to a number of solid discoveries, such as that the expanding universe creates particles and that black holes create particles with a thermal spectrum, that have had a profound and lasting influence on our conception of the early universe and of the fundamental connection between thermodynamics, quantum theory, and general relativity. Connections between thermodynamics and quantum gravity are explored in papers by P. C. W. Davies, Sciama, R. M. Wald, and Penrose.

There is almost no doubt that a complete theory must include gravity within its quantum framework. In an important contribution, B. S. DeWitt, one of the pioneers of quantum gravity, develops a gauge invariant effective action that may allow one to compute the influence of quantum gravity on the possible formation or avoidance of the cosmological singularity. Using an effective action approach, J. B. Hartle reviews particle production and the dynamics of the early universe. Also of importance in the early universe is acausal propagation in quantum gravity, which is discussed by S. W. Hawking. The canonical approach to quantizing the gravitational field is comprehensively reviewed by K. Kuchař. Supergravity, a significant attempt to create a renormalizable quantum theory of gravity by imposing a symmetry that includes both fermions and bosons, is reviewed by Duff, P. van Nieuwenhuizen, S. Ferrara, and K. S. Stelle and P. C. West.

There are other significant contributions in the book, which space does not permit me to discuss. In summary, the volume surveys much of the current research in quantum gravity and is highly recommended to researchers and graduate students.

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Hurricanes

Tropical Cyclones. Their Evolution, Structure and Effects. RICHARD A. ANTHES. American Meteorological Society, Boston, 1982. xviii, 208 pp., illus. $40. Meteorological Monographs, vol. 19, no. 41.

Much of our early knowledge about hurricanes came from William Redfield, who deduced from just a few observations made in the Long Island Hurricane of 1821 that the storm was "in the form of a great whirlwind." He was followed by many other investigators who compiled small quantities of data from many sources and deduced much information about the structure and forecasting of these tropical cyclones.

It was not until the middle of the 20th century, however, that there was a great expansion in hurricane research. The development of radar and aircraft reconnaissance of hurricanes during World War II and the weather satellite in the 1960's provided tools to obtain detailed information about hurricanes and to obtain information more often and reliably. Prior to 1940 a forecaster who issued an advisory about a hurricane frequently lost most of the information needed for making forecasts as ships warned of the hurricane headed for safer waters. Hurricane disasters in 1954 and 1955 provided motivation for Congress to expand support of hurricane research, and our understanding of hurricane structure and energy processes soon doubled.

The development of the high-speed computer in the 1950's greatly facilitated theoretical investigations of the development, movement, and dissipation of the tropical cyclone. Efforts were soon started to simulate the development and forecast the movement of tropical cyclones with numerical models. The work of the experimentalists and that of the theoreticians complemented and supported each other and enabled the total research effort to advance much more rapidly.

This book summarizes the research from the time of Redfield until about 1980. It is not merely a summary, however. The author traces the development of our knowledge in each of the several areas, and he also summarizes present knowledge, analyzes the strong and weak points in our understanding, and suggests what can practically be accomplished in the future. This is done for the structure and life cycle of tropical cyclones, physical processes in tropical cyclones, simulation by numerical models, hurricane modification experiments and theory, interaction between ocean and atmosphere, and forecasting of the movement of the tropical cyclones. The section on oceanic response includes a thorough discussion of the forecasting of the storm surge associated with hurricanes, which is the cause of the most damage due to hurricanes along the coast.

For the research scientist this is an excellent book. Much of the information in the chapters on hurricane structure and forecasting would be understandable to the nonprofessional, and even in the chapters written for the professional the writing is so good and concise summaries are so frequently put in simple English that a person with a general scientific background would understand many of the points being made. Summaries and discussions of errors in hurricane forecasting would be valuable for anyone who has to make decisions about hurricane preparedness.