African grassland communities. The parallel is probably more with the comparably diverse but sparse ungulate faunas that existed historically in African deserts or semideserts such as the Kalahari or the Karroo.

One implication of this is that glacial Beringia was not a particularly hospitable place for human hunter-gatherers, and it is perhaps not surprising that the parts that are still exposed have provided little evidence for Pleistocene people. The time when they first appeared in Beringia remains a matter of debate. As summarized in this book, the oldest incontestable stone artifacts in eastern Beringia (Alaska and the Yukon) are no more than 15,000 years old. However, some specialists believe that fractured animal bones from the Yukon imply human penetration of Beringia at least 60,000 years ago. One difficulty with this position is that it has not been shown that people were present in Siberia (the sourceland for Beringian colonization) prior to 35,000 years ago.

The issue is closely tied to the question of whether people lived south of the Canadian–United States border before the universally accepted Clovis "Culture," well dated at between about 11,500 and 11,000 years ago. Those who see evidence for pre-Clovis occupation tend to favor an early penetration of Beringia, certainly before 15,000 years ago. Those who feel that pre-Clovis evidence is tenuous tend to favor a relatively late penetration. The time of earliest human colonization may never be fully resolved for either Beringia or the Americas as a whole, since archeologists cannot agree on what constitutes reasonable evidence for ancient human presence. Some require abundant, indisputable cultural debris in well-stratified sites like numerous African and Eurasian ones that date back tens or even hundreds of thousands of years. Others feel that unstratified materials of potentially great antiquity or stratified materials of arguable cultural origin are sufficient, particularly if many such occurrences can be cited. Both points of view are represented in this volume.

Unlike the participants in many similar conferences, the contributors to this one consistently focused on the same broadly interesting ecological and historical problems. In addition, the editors have successfully tied the book together with thoughtful section introductions and a comprehensive concluding synthesis. The result is a book that truly belongs between two covers. I highly recommend it not only to professional paleoecologists and prehistorians but to anyone who wants to see how skilled specialists can weave disparate paleobiological, geological, and archeological facts into a remarkably complete picture of a long-dead landscape.

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Ocean Science

Oceanography: The Present and Future. Papers from a symposium, Woods Hole, Mass., Sept. 1980. PETER G. BREWER, Ed. Springer-Verlag, New York, 1983. xii, 392 pp., illus. $39.80.

This inhomogeneous collection of papers presents the written versions of lectures given on the 50th anniversary of the founding of Woods Hole Oceanographic Institution. Compared with the sumptuous festschrift recently prepared for the 60th birthday of Henry Stommel from the same institution it is modest both in its physical presentation and in its content. It consists of 22 papers on a wide diversity of oceanographic topics. The authors have been asked to address the current status of and trends for the next 50 years in their specialties. The latter task is of course almost hopeless. With few exceptions—notably Peter Larkin on fisheries and productivity and Evelyn Murphy on environmental problems and public policy in the next 50 years—the authors made no serious attempt to address future trends.

The six or seven thousand words per paper are little indeed within which to attempt a comprehensive review of even a narrow subject. Nevertheless, despite such almost insuperable constraints, the volume is remarkably successful, probably because of the undoubted quality of the contributors themselves—Christopher Garrett ("Coastal dynamics, mixing, and fronts"), Walter Munk ("Acoustics and ocean dynamics"), Pearn Niiler ("General circulation of the oceans"), Bert Bolin ("Changing global biogeochemistry"), and John Steele ("Institutional and education challenges"), to name but a few. My list exaggerates the international character of the authors. Only five work outside the United States and only a couple outside "anglophonia." However, American scientists are so dominant in the front line of oceanography that this concentration may not be unfair. (A combination of language problems and the political atmosphere of the day probably prevented the invitation of that other very large group of oceanographers—the Soviets.)

The authors have used their space in varying ways. Most have chosen to address an audience wider than those in their own specialty, and some, including Munk, Frank Carey ("Experiments with free-swimming fish"), and James Childress ("Oceanic biology: lost in space?"), have written with a transparency that makes their papers widely accessible. An unfortunate counterexample is a paper by John Wood, "Molecular processes in the marine environment," which opens the volume, and which demonstrates the massive chemical difference between the marine and the freshwater environments. The paper is exceedingly important; it deserves study by regulators and environmentalists, but such sentences as "This unique cytochrome regulates electron flow in a multifunctional mode with pathways to sulfite reduction and H_2 formation" make it pretty heavy going, and it may not reach the right people. Another paper that deserves examination by regulators and politicians is that by Orrin Pilkey ("Shoreline research"). Pilkey's view that by resisting the erosion we may be doing more harm than good needs to be listened to. It is presented in clear English and should be accessible to anyone.

This volume will certainly be in libraries. I hope it will be taken out and read by those interested in understanding the scope of modern oceanography. It also belongs in the private library of any oceanographer who has pretension to being even somewhat eclectic. Uneven though it is in content and unprepossessing though it is in form, it contains material of real value.

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Strong Interactions

Lectures on Lepton Nucleon Scattering and Quantum Chromodynamics. W. B. ATWOOD, J. D. BJORKEN, S. J. BRODSKY, and R. STROYNOWSKI. Birkhäuser, Boston, 1982. viii, 566 pp., illus. $29.95. Progress in Physics, vol. 4.

Quantum chromodynamics (QCD) is a precise and complete theory of quarks and gluons that purports to be an ultimate explanation of all strong interaction experiments at all energies, high and low. There are many reasons to hope and expect that it is right. The question is, is it indeed right? Its mathematical complexity has so far prevented the quantitative testing of its correctness. The past ten years have been unusual in that we have what we believe is the correct theory of strong interactions, although we have not been able to make precise calculations to compare with experiment and thus prove that the theory is correct.

An annual summer institute on particle physics at the Stanford Linear Accelerator Center (SLAC) has for the past nine years provided an excellent forum for the confrontation of high-energy theory with experiment. This book is a collection of four lectures originally given at the seventh of these institutes. The lectures explain the development of high-energy theory from the parton and quark model to our present understanding of QCD.

The primary obstruction to making precise calculations is that the fundamental quarks and gluons of QCD apparently cannot be isolated as free particles but are always confined within hadrons (protons, pions, and so on) by strong forces not amenable to treatment by perturbative methods. Nevertheless, because QCD is an asymptotically free theory, interaction forces become weak at small distances (large energies) and calculations using perturbation theory and Feynman diagrams are possible. Unfortunately, most processes involve both low- and high-energy aspects, and ways of separating the low-energy pieces, which are not calculable by perturbative methods, from the high-energy perturbative ones are just becoming understood.

Because of our inability to make one precise calculation to compare with experiment, evidence in support of QCD as the correct underlying theory comes from its success in approximately describing a wide class of physical phenomena. As is discussed in detail in the lecture by Atwood, QCD correctly describes data on the deep inelastic scattering of electrons and neutrinos off protons and neutrons. In his lecture Stroynowski shows that the theory also describes correctly the data on massive muon pair production in proton-proton and pion-proton collisions and gives a good qualitative understanding of the production of large transverse momentum hadrons and "jets" in hadron-hadron collisions. Brodsky shows in his lecture that perturbative QCD can be applied with success to a wider class of phenomena than originally expected. He presents some of his original work showing that perturbative QCD can be applied to large transverse momentum exclusive processes. In addition, he very clearly discusses the applications of perturbative QCD to the pion and proton form factor.

The lectures give a feeling of the fun, excitement, and sometimes frustration particle physics has provided over the past ten years. The fun began around 1968 when it became evident from deep inelastic scattering experiments at SLAC that the proton was not elementary but was composed of constituents or pieces (called "partons"). After many experiments it became evident that partons had the quantum numbers of quarks but that the quarks carried only about 50 percent of the momentum of a fast-moving proton. The remaining momentum, presumably, was carried by the gluon, the object mediating the force between the quarks. Efforts to knock a quark out of the proton and view it directly in the laboratory were fruitless. Instead of the struck quark, experiments detected a collection of roughly parallel moving hadrons called a "jet." The study of jets became synonymous with the study of quarks. The jet was the realization in the laboratory of the initiating quark. The challenge for theorists was to come up with a theory that could explain how at short distances the proton could behave like a collection of essentially noninteracting quarks whereas once the quark was knocked a distance out of the proton the forces became enormous, resulting in the production of ordinary hadrons in the form of a jet.

The situation became clear after the invention and comprehension of the theory of quantum chromodynamics, with its feature of asymptotic freedom. Experiments changed from simply observations of nature to "tests of QCD." Every effort is being made to make precise calculations to compare with experiment. The frustration lies in our present inability to do this. However, as these lectures show, all the qualitative features expected from the theory are seen in the data. The theory is so simple and beautiful and the qualitative evidence from a wide class of experiments so overwhelming that most theorists now believe that QCD is indeed the correct theory of the strong interactions between quarks and gluons.

Bjorken's lecture is, as always, clear and informative, adding extra insight into the subject. I particularly enjoyed his discussion of gluonium. Unlike quantum electromagnetism, in which photons do not couple to each other, in QCD gluons interact with each other and can form interesting states of matter called "glue balls" (or gluonium), which contain no quarks. It is an important test of QCD to find decisive evidence for or against the existence of these pure gluon states of matter. Experimentally one would look for neutral hadrons that do not fit into the normal quark-antiquark spectrum. Many high-mass gluonium states are predicted by QCD. Bjorken's lecture contains detailed discussions of the expected spectrum of states together with an examination of their decay schemes and production mechanisms.

This collection of lectures is a bit too technical for the layperson; however, it will be of benefit to beginning and advanced graduate students. It should also be useful to experimental high-energy physicists who want to keep abreast of current theory and to particle theorists doing research on other subjects who would like to keep informed of the progress in perturbative QCD.

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