that I should like to recommend it to a large audience, but some reservations should be noted. The author has chosen not to make Jakob a "fully developed character in his social world," so that the book is not quite satisfactory as a novel. Also, even the readers of *Science* cannot be expected to recognize the names of relatively obscure physicists who enter the pages of this book with little introduction, along with giants like Max Planck and Albert Einstein. That being said, however, I recommend this book for its charm, its intensity, and its scholarship.

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Lectures in Particle Physics

The Nature of Matter. Wolfson College Lectures 1980. J. H. MULVEY, Ed. Clarendon (Oxford University Press), New York, 1981. xiv, 202 pp., illus. $15.95.

In the spring of 1980, eight lectures on the status of elementary particle physics were given at Oxford's Wolfson College. The cast of distinguished speakers consisted of Denys Wilkinson, Rudolf Peierls, C. H. Llewellyn Smith, D. H. Perkins, Abdus Salam, John Ellis, J. B. Adams, and Murray Gell-Mann. All have made important contributions to our understanding of the fundamental laws of nature and are well known for their ability to deliver clear narrations. J. H. Mulvey has collected and edited these talks in a neat, concise book that is a delightful survey of contemporary elementary particle physics.

I was impressed by all eight lectures; but I most enjoyed the two experimentally oriented papers, "Inside the proton" by Perkins and "The tools of particle physics" by Adams. The first is a lively account of the quest for the elusive quark. Although free quarks have never been observed and many physicists believe that they are permanently confined inside hadronic matter, deep-inelastic electron-proton scattering experiments have nevertheless managed to unveil their basic properties. Perkins explains in simple terms how such experiments have determined the fractional charge, spin (1/2), and "effective" masses of quarks. Those same experiments revealed a peculiar feature of quarks. Their interaction strength diminishes at short distances. This remarkable discovery inspired the development of quantum chromodynamics (QCD), the popular gauge theory of strong interactions. Perkins's description of this advancement in theory and experiment makes for very interesting reading.

In Adams's exposé on the tools of particle physics, the key adjective is big. Today's high-energy experiments are carried out by big collaborations (as many as 100 physicists) at big accelerators (several miles of circumference) using big detectors producing extremely large amounts of data. From his own firsthand experience, Adams provides a fascinating description of the unique world of today's high-energy experimental physicist. His paper also serves as a brief introduction to the next generation of even bigger accelerators (Large Electron-Positron, Isabelle, and Tevatron), which, when completed, will probe yet smaller distances.

The six theoretical papers are all clear, concise, and readable. They deal with the fundamental forces, attempts to unify these distinct interactions, proton decay, the use of symmetry in our attempts to understand nature, and the relationship between particle physics and big-bang cosmology. Together, the papers provide an up-to-date overview of the present theoretical scene.

The book concludes with Gell-Mann's lecture "Questions for the future." This is a witty monologue by one of the outstanding physicists of our day. It provides a nice perspective on how far theoretical physics has gone and what questions remain to be answered, particularly the question how do we unify gravity with the other fundamental forces? Having heard Gell-Mann speak on this subject at several colloquiums, I was delighted to finally see his thoughts and anecdotes in print.

In summary, *The Nature of Matter* is a well-written, informative collection of superb papers. I highly recommend it. It is particularly well suited for students and nonspecialists who seek a clear, concise overview of the recent progress in elementary particle physics. However, even the experts will be entertained by the book.

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New Instruments for Exploration

Telescopes for the 1980s. G. BURBIDGE and A. HEWITT, Eds. Annual Reviews, Palo Alto, Calif., 1981. x, 278 pp., illus. $27. Annual Reviews Monograph.

Astronomy is an observational science, critically dependent on the collection of photons from distant objects. The rapid advances of the past three decades have come about primarily in response to improved telescopes and detectors and expansion into previously unexplored regions of the electromagnetic spectrum. In the 1950's, the 200-inch telescope on Mount Palomar and the rapid development of radio astronomy led the way. The 1960's saw the impact of the new national observatories at Kitt Peak and Cerro Tololo, the introduction of electronic detectors, and the first successful observations in x-ray and ultraviolet from above the atmosphere. During the 1970's, the number of large optical telescopes in the world more than doubled, infrared and millimeter-wave astronomy came into their own, high-quantum-efficiency array detectors began supplanting photographic plates for optical work, interferometry and aperture-synthesis techniques enabled radio astronomy to achieve high spatial resolution, and high-energy astronomy from space revealed a variety of new phenomena. Astronomers now study a universe far more dynamic than any imagined a generation ago, one populated by molecular clouds, exploding galaxies, quasars, blazars, and black holes. Equally dynamic is the observer's quest for the new instruments needed to pursue this revolution—instruments that frequently require large resources of scarce federal research dollars as well as substantial technological innovation.

This book tells the story of the development of four major new astronomical instruments—or facilities, as such multiuser equipment tends to be called these days. Three of these represent the latest generation of radio, optical, and x-ray telescopes, each built during the late 1970's, and the fourth, the NASA Space Telescope, is still under development. The x-ray telescope, Einstein, has already completed its rather brief lifetime, while the other three promise to be among the major facilities that will provide the astronomical discoveries expected during the 1980's.

The Very Large Array (VLA) is the name given to the multielement, aperture-synthesis antenna array built by the National Radio Astronomy Observatory (NRAO), with $78 million in funds from the National Science Foundation. Completed early in 1981, this telescope consists of 27 movable antennas, each 25 meters in diameter, capable of working together to provide a spatial resolution at wavelengths of 21 centimeters, 6 centimeters, 2 centimeters, and 1.3 centimeters, comparable to that of the best optical telescopes. David Heeschen, former director of the NRAO, describes the series of political, financial, and technological hurdles that had to be surmounted over a 10-year period to bring this dream to reality, covering the gamut from on-site salvage archeology to a nationwide search for used railroad rails to the decisions that led to the use of a daring new approach for the waveguides needed to provide the critical electrical linkage of the separate antennas. The VLA represented the major capital project in the NSF astronomy budget during the 1970's, and so far no new initiative of this magnitude has developed as a successor.

The second chapter in this monograph deals with the Multiple Mirror Telescope (MMT) built at Mount Hopkins (near Tucson) by the University of Arizona and the Smithsonian Astrophysical Observatory. A substantially more modest undertaking than the others described in this book, the MMT is a test-bed for new approaches that will be required for the much larger optical telescopes being planned for the late 1980's and beyond. A conventional large telescope mirror of ceramic material becomes too heavy and difficult to maintain in precise optical figure for diameters much greater than that of the 6-meter telescope in the U.S.S.R., now the world's largest. The MMT achieves a much more compact design by combining the images from six mirrors, each of 1.8-meter diameter, to produce the light-gathering power of a single mirror of 4.5-meter diameter. As described by its director, Jacques Beckers, and ten other authors, this telescope introduces many innovations in mechanical as well as optical design, including an altazimuth mount and a rotating building instead of the more conventional dome. The greatest challenge has been to maintain the optical alignment; an elaborate laser system has now been abandoned in favor of an approach that uses the stellar images themselves. The more difficult task of also obtaining phase alignment has so far been successful for only two mirrors at a time, but work continues on this problem.

Unlike the other instruments described here, the Space Telescope (ST) has not yet been built. Designed for shuttle launch in 1985, the ST is a nearly billion-dollar project that represents NASA's single largest space science effort in the 1980's. The telescope, of 2.4-meter aperture, will achieve its primary advantage by escaping the limitations of the terrestrial atmosphere on resolution, permitting it to realize the 0.1 arc second resolving power of the optics. Smaller star images will yield a higher signal-to-noise ratio for faint sources, thus permitting as much as a 50-fold increase in sensitivity relative to ground-based telescopes. Project scientist C. R. O'Dell discusses the checkered history, and the great potential, of this instrument. It is almost an article of faith for astronomers today to rally around the ST, but one must note that there remain many problems to solve, particularly with the fine-guidance system, before the telescope can be called a success.

Riccardo Giacconi and seven colleagues from the Harvard-Smithsonian Center for Astrophysics describe, in the final chapter, the Einstein x-ray observatory, launched in 1978 as the culmination of a decade of planning that included several smaller x-ray satellites. The distinguishing characteristic of Einstein (officially called HEAO-B by NASA) was the use of grazing-incidence optics to create a true telescope with imaging capability, as opposed to the wide-field detectors flown previously. During its 2½-year lifetime, this telescope provided our first pictures of the x-ray universe, a unique window on high-energy process es in space. Giacconi and colleagues trace the history of x-ray astronomy, in which they have played a leading role from the beginning. They also discuss the next generation x-ray instrument, AXAF (Advanced X-Ray Astrophysics Facility), a proposed billion-dollar program anticipated for the late 1980's, but rapidly receding into the future as cuts in the NASA science budget become ever heavier. Perhaps it is a sign of the times that Giacconi, after two decades of advocacy for x-ray astronomy, has changed fields to become director of the Space Telescope Science Institute.

One common element of the four chapters is that protracted political battles had to be fought—often over and over again—to make each of the facilities a reality. This book should shatter the illusion, if anyone still holds it, that modern astronomy is an academic, ivory-tower pursuit, carried on independent of the high competition and bureaucratic tangles that characterize "big science" in the United States today. A major new instrument requires at least a decade of intense effort, half of it expended before official approval to begin is ever granted. All of this is worthwhile if the end result is the successful development of major new capabilities, but it becomes a tragic misuse of our best scientific and administrative talent if the result is repeated deferment and ultimate cancellation, which seems to be the recent pattern under shrinking federal science budgets. Anyone contemplating beginning a major new science facility should read this book and think hard before making such a commitment.

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Planetary Geology

The Surface of Mars. MICHAEL H. CARR. Yale University Press, New Haven, Conn., 1981. xii, 232 pp., illus. $45. Yale Planetary Exploration Series.

Unlike some earlier books published to coincide with peak popular interest as a spacecraft arrived at the planet in question (hence guaranteeing overnight obsolescence), this book comes at the end of the Viking program, after its author, as the leader of the Viking Orbiter Imaging Team, has devoted several years to absorbing the meaning of Viking, Mariner, and ground-based data about Mars. The book is an excellent and evenhanded survey of the current state of research about Mars.

Writers who try to summarize the knowledge of a whole planet run the risk of producing a few terrific chapters on their own specialty, only to lapse into superficiality on other subjects. Michael Carr has done a remarkably good job of overcoming this problem. He has capitalized on his close work with Viking colleagues in various disciplines, and he has also made a rewarding effort to review a broad range of pre-Viking and post-Viking literature. This enables him not only to discuss recent prominent