the arts (the horse in the book title is a sculpture Djerassi owns), and in recent years he has become a published writer of novels, short stories, and poems. Especially in the later autobiography Djerassi provides a poignant account of his unconventional childhood, of his three marriages, and of his sometimes strained interactions with his son and daughter. His decision to reveal so much of a personal nature in this volume in itself represents a new direction in his life and results in our learning much more than we might have expected from a scientist's autobiography. Though the interplay between his private life and his professional one is not really explored, Djerassi may nevertheless have set a new standard for openness in a work of this character. Overall, Carl Djerassi's ability to overcome difficulties of both a physical and a spiritual nature, his startling combination of competitive spirit and altruism, his breadth of interest, and his successful move away from scientific research and into entirely new fields of endeavor at a stage when many would be quietly retiring are all portrayed with clarity and enthusiasm in these complementary accounts of a rich and complex life.

Jerrold Meinwald
Department of Chemistry,
Baker Laboratory,
Cornell University,
Ithaca, NY 14853–1301

So-Called Quasicrystals

Quasicrystals. The State of the Art. D. P. DIVINCENZO and P. J. STEINHARDT, Eds. World Scientific, Teaneck, NJ, 1991. x, 524 pp., illus. $58; paper, $28. Directions in Condensed Matter Physics, vol. 11.

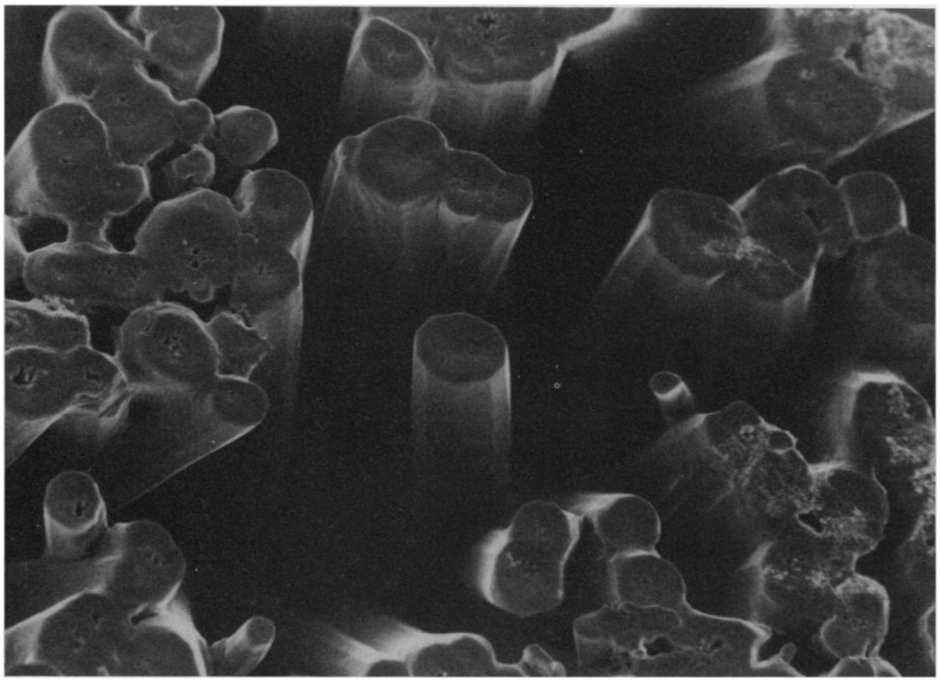
As many readers will recall, the 1984 announcement by Schechtman, Blech, Gratias, and Cahn of the discovery of AlMg alloys with icosahedral symmetry sent shock waves through the world of solid state science. Since the beginning of the 19th century, it had been almost universally accepted that icosahedral symmetry was incompatible with periodicity, and several hundred years of mineralogy and crystallography had laboriously established the hypothesis that crystal structure is periodic. It was therefore assumed that icosahedral symmetry was impossible for a crystal, so when researchers were confronted with a crystal that exhibited this symmetry their immediate response was to call it something else. Eight years later, we seem to be stuck with the term "quasicrystal," despite the fact that today many crystals with "forbidden" symmetries are known.

That the distinction between "crystals" and "quasicrystals" is highly artificial and should be abolished is in fact the point of view taken by David Mermin, one of the authors in *Quasicrystals*. Mermin argues that the symmetry groups of crystals and quasicrystals can and should be placed together in a single conceptual classification scheme. By focusing on the groups, rather than the structures whose symmetry they describe, he avoids dealing with rather complex models for quasicrystal structures. However, the object of quasicrystal research is to determine the structure of quasicrystals, so the problem of characterizing the structures whose symmetry is described by the groups remains a central one.

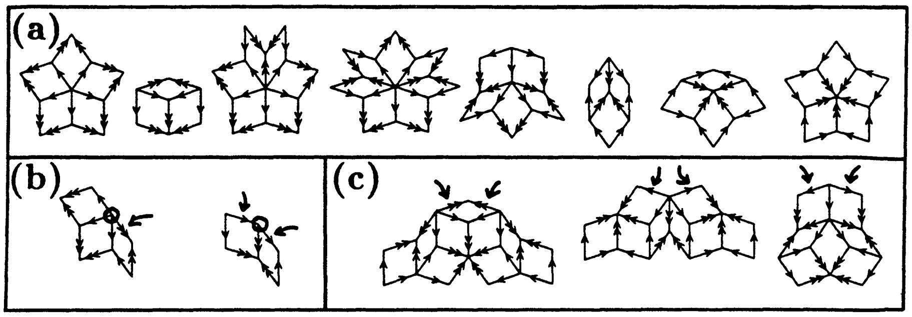
Two early models, intricate twinning and icosahedral glasses, no longer seem viable. Tilings, on the other hand, continue to be studied intensively. Tiling models stimulate geometric intuition and imagination, are amenable to calculation, and pose many problems that are at least superficially analogous to those posed by quasicrystals. For example, the debate over the respective roles of energy and entropy in stabilizing quasicrystals can be formulated in tiling language: Are quasicrystals better modeled by "classical" Penrose tilings (whose structure is determined by matching rules) or by "random" tilings, in which the same shapes are used but the matching rules are relaxed? Both points of view are vigorously represented in this book, though Penrose models serve as the starting point for most of the investigations. The range of physical problems explored through such models includes quasicrystal growth, facet and surface roughening, electronic structure, and transport.

Important information about tiling models is obtained by "lifting" the tilings to higher-dimensional spaces, in which they can be seen as sections or projections of periodic patterns (lattices with an "atomic surface" attached to each lattice point). Conversely, large classes of orderly but nonperiodic point sets can be obtained by section or projection, including point sets that cannot be meaningfully associated with tilings. Higher-dimensional methods are extensively used in the analysis of diffraction data. Unfortunately, structure determination is underrepresented in this book.

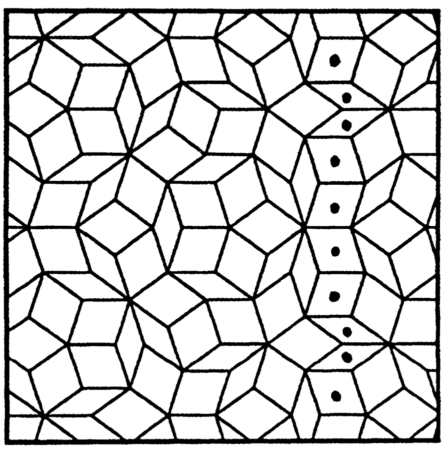
Although the editors describe *Quasicrystals* as a "progress report" that "takes stock of the current state of affairs in the science of quasicrystals," there are several respects in which the contributions do not fully portray "the state of the art." This most probably results from the fact that the collection reflects the interests of researchers at the two main centers of quasicrystal research in the United States—the University of Pennsylvania and Cornell. Most of the authors are or have been connected with one or the other of them. To be sure, the



"Decagonal prismatic solidification morphology of a single grain Al-Co quasicrystal. In the ternary $Al_{65}Co_{20}Cu_{15}$ or $Al_{70}Co_{15}Ni_{15}$ form the decagonal phase becomes a stable compound and single grains of several millimeters can be grown." [From R. S. Becker and A. R. Kortan's chapter in *Quasicrystals*]



"The [Onoda-Steinhardt-DiVincenzo-Socolar] classification of sites for Penrose tiling growth. (a) The eight allowed vertex configurations, shown with the edge-arrow decoration of the tiles. (b) Examples of forced edges. There is only one way to add to the edges indicated, owing to the structure around the circled vertex. Note that in the case on the left, the edge is forced even though the entire vertex may be either the third or fourth from the left in (a). (c) The edges indicated are classified as marginal." [From J. Socolar's chapter in *Quasicrystals*]



"A perfect Penrose tiling. The dotted sequence of tiles is referred to as a track." [From Tin-Lun Ho's chapter in *Quasicrystals*]

selection is not parochial—some important Japanese and European work is also included. However, a more balanced portrait of the field would give more weight to structure determination and would include a summary of the extensive body of work that takes the scaling properties of quasicrystals (and Penrose tilings) as its starting point. I would have also liked to see a more complete picture of current research on related mathematical problems.

Despite these reservations, this book is timely and useful. The editors have assembled an impressive collection of essays on recent advances in many areas of quasicrystal studies, both experimental and theoretical. On the experimental side, there are reports on high-resolution electron microscopy and scanning tunnel microscopy, as well as studies of electronic transport, order and disorder in icosahedral alloys, and neutron scattering. On the theoretical side, there are discussions of tiling models, energy calculations, and even the possibility that some liquid crystals (chiral smectics) might be quasicrystals. Most of the contributions are well written and jargon-free, a noteworthy achievement in a field that is famous for its bewildering opacity.

The issues addressed in this book are central, and the authors are indeed "leading experts in their areas, and are engaged in the cutting-edge research that they describe." However, the editors' assertions aside, it is not a book for beginners. Readers approaching the subject for the first time are advised to spend some time acquiring the necessary background—for example, by way of *Introduction to Quasicrystals* (Academic Press, 1988) and *Introduction to the Mathematics of Quasicrystals* (Academic Press, 1989), both edited by Marko Jaric, or *The Physics of Quasicrystals* (World Scientific, 1987), edited by P. J. Steinhardt. That said, I recommend this book to those in the field and to everyone sufficiently interested in quasicrystals to invest the time and energy needed to understand them.

Marjorie Senechal
Department of Mathematics,
Smith College,
Northampton, MA 01063

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Planetary Reconnoiter

Uranus. JAY T. BERGSTRALH, ELLIS D. MINER, and MILDRED SHAPLEY MATTHEWS, Eds. University of Arizona Press, Tucson, 1991. xiv, 1076 pp., illus. $65. Space Science Series. Based on a colloquium, Pasadena, CA, June 1988.

In 1781, Sir William Herschel found, quite by accident, the first new planet—that is, a planet that had been unknown to the ancient civilizations—in our solar system. Although the discovery of Uranus created quite a stir at the time, the remoteness of the planet caused it to remain very poorly understood for nearly two centuries. Until recently, textbooks and encyclopedias mentioned little more than the details of its discovery, its size and orbit, and a few other sparse facts. Uranus was believed, along with the other giant planets—Jupiter, Saturn, and Neptune—to be composed largely of the lighter elements, hydrogen and helium, along with some heavier materials, such as methane, water, and rock. Five small-to-medium-sized satellites had been discovered, and their individual orbital motions indicated that the rotation axis of Uranus was so strongly inclined to its orbital plane that the planet seemed to roll along on its side as it circled the sun.

About two decades ago technological advances in astronomical instrumentation began to give us new insight into the more remote bodies of our solar system. Uranus was found to be alone among the four giant planets in not radiating a measurable amount of excess, primordial heat. Water ice was identified on the surfaces of its larger satellites. In 1977, astronomers were taken aback by the surprising discovery of nine narrow rings surrounding Uranus, an event that forever deprived Saturn of its long-held unique status. Still, the tiny telescopic disk of Uranus remained nearly featureless to even the most advanced detectors, lacking the discrete clouds that could have revealed the planet's period of rotation and its global atmospheric circulation; to a large extent, Uranus remained an enigma. All this changed in 1986 when the Voyager 2 spacecraft flew through the Uranus system and sent back a wealth of scientific observations of this curious planet. Almost overnight, Uranus passed from the unknown to the known.

Uranus is the latest addition to the superb Space Science Series published by the University of Arizona Press and is based on a colloquium held at the Jet Propulsion Laboratory two years after the Voyager 2 encounter. Not surprisingly, the contributions strongly emphasize the data acquired by Voyager. The book presents an excellent, balanced review of our current perception of the entire Uranus system, including the interior and atmosphere of the planet itself and its rings, satellites, and magnetosphere. Although there is now a very much better understanding of the physics and chemistry that characterize the various components of the system, the reader will note that this new knowledge also poses many new questions and that much still remains to be learned. A case in point is Miranda. A mere 484 kilometers across and the smallest of the five earlier known Uranus satellites, Miranda was one of the great surprises to be captured by the Voyager cameras. Highly diverse and puzzling geological units are seen in close juxtaposition, with transition regions barely a few hundred meters wide. An entire chapter is allocated to this satellite alone. It begins, "Miranda is arguably the strangest body to have been reconnoitered in the age of planetary exploration, especially if the criterion is the gulf between unique char-