that are familiar from the standard texts, such as construction of hybrid orbitals or ligand field theory, are not discussed at length here. Yet several other applications are described quite thoroughly, with detailed examples. This book thus complements the existing literature, with extensive references included for each chapter.

As is perhaps inevitable in a book with such a broad perspective, parts are somewhat uneven. Chemistry is introduced at a very fundamental level (what is a molecule? what is the meaning of an empirical formula?), yet by the end of the same chapter permutational isomerism is discussed. It is hard to imagine a reader who could make such rapid progress. Similar leaps are made in other chapters.

The book begins with an introduction to the idea of symmetry, basic symmetry elements, and properties (polarity, chirality) that depend on the presence or absence of symmetry elements. A 10-page discussion of snowflakes illustrates the authors' approach: first they describe snowflake growth and form in terms of the marginal stability model; they follow with a passage on snow from Thomas Mann's *The Magic Mountain* and a brief history of interest in snowflakes from ancient China through modern Europe; finally, they provide a beautifully illustrated description of the classification of snow crystals.

Chemistry enters in chapter 3, beginning with point groups. The elegant symmetries presented by network molecules like boron hydrides and polycyclic hydrocarbons are described. There is a good discussion of the valence shell electron pair repulsion (VSEPR) model, which in recent years has become an established part of the general chemistry curriculum but is not often discussed in more advanced texts. The elements of group theory are given in chapter 4, with a clear presentation of the concept of a representation. Though informal, the Hargittais' approach establishes basic terminology and builds quickly to the results and tools essential for chemical applications. Chapters 5 and 6 describe the use of group theory in the study of molecular vibrations and molecular electronic structure. The discussion of the construction of symmetry-adapted linear combinations of atomic orbitals is excellent, including for several molecules a comparison of simple cartoon representations generated by symmetry analysis with contour diagrams of molecular orbitals generated by *ab initio* electronic structure calculation. Chapter 6 closes with a curious critique of the current status of electronic structure theory.

The chapter "Chemical reactions" describes the symmetry of the reaction coordinate, frontier orbital concepts, and Woodward-Hoffmann rules. The development is brief, probably inaccessible to someone unfamiliar with these important topics. However, the comparison of the three viewpoints as applied to several systems is valuable. The final chapters deal with translational symmetry: space groups and crystals. This material is richly illustrated, including along with crystals Hungarian needlework patterns and drawings by M. C. Escher.

Chemists, familiar with the use of symmetry in some of these areas, will find this book interesting and enjoyable. Many of the examples and illustrations are beautiful, some are whimsical, a few even a bit forced, but that is a matter of taste. The depth of the treatment varies, but the book gives a fascinating overview of the rich variety of applications of symmetry throughout chemistry, showing both its power and its aesthetic appeal.

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Lectures on Weyl

Hermann Weyl, 1885-1985. K. CHANDRASEKHARAN, Ed. Published for the Eidgenössische Technische Hochschule, Zürich, by Springer-Verlag, New York, 1986. viii, 119 pp., illus. $30. From a celebration, Zürich.

This book contains the three lectures delivered for the celebration of Hermann Weyl's centenary at Zürich. It also contains a complete list of his publications (including mimeographed lecture notes), three pages of Weyl memorabilia, four pages of pictures, and 12 pages entitled "Report on the celebration," half of them devoted to Michael Weyl's speech about his father. The three lectures, given by Chen Ning Yang (15 pages), Roger Penrose (30 pages), and Armand Borel (30 pages), are rather different in style.

In his lecture "Hermann Weyl's contribution to physics," Yang gives many quotations from Weyl. He recalls several pieces of Weyl's work relevant to physics and sketches the current status of these different topics. First, he tells of Weyl's work on the distribution of eigenfrequencies of a vibrating plate; this partly answered a question that had been raised by Lorentz. A more direct involvement of Weyl in physics was his rebuttal of Dirac's proposal in 1929 that protons could be represented by the holes in the sea of negative energy electrons: Weyl, in the second edition (1930) of his book *Gruppentheorie und Quantenmechanik*, showed that the Dirac equation has a built-in symmetry, so the mass of the hole must be that of the electron; "furthermore, no matter how the action is chosen (so long as it is invariant under interchange of right and left), this hypothesis leads to the essential equivalence of positive and negative electricity under all circumstances." In addition, Weyl pointed out the possibility of a relativistic, two-component spinor equation when the particle has zero mass: this is the equation currently used for neutrinos (it violates P and C). Finally, Weyl maintained a continuing interest in gauge theories; Yang distinguishes three periods in this work and relates it to his own interest in these theories, discussing some topological effects (such as the Aharonov Bohm experiment).

Penrose's lecture "Hermann Weyl, space-time and conformal geometry" is inspired by Weyl's work but deals essentially with the lecturer's own research. First, he tells of the interesting history of the nonperiodic pavings of the plane, and of his own contribution and its relevance to the recently discovered quasicrystals. Without transition, he moves to what he calls Weyl's spaces—axisymmetric solutions of Einstein equations with two-point masses—and explains in a rather cryptic manner his recent, unpublished work on their topological properties. In the last part, he recalls Weyl's work (with Brauer) on spinors in n-dimensions and the work in general relativity using conformal geometry. These two topics have been blended by physicists, Penrose among them. He ends his lecture with a description of his recent work in quantum gravity. It is daring: The origin of the second law of thermodynamics might be a speculative "objective state-vector reduction," a purely quantum-gravity effect that does not require the intervention of an observer.

Borel's lecture "Hermann Weyl and Lie groups" is a scholarly study of Weyl's work on this subject (presented against the historical background), his interaction with other mathematicians, his influence, and some glimpses of later progress. The study is precise, even technical, but the reader is greatly helped by long explanatory notes at the end of the paper. Borel quotes not only the original papers but also Weyl's correspondence and writings by historians of science on Lie groups. He explains how Weyl was casually led to this subject, at the age of 37, by his reflections on relativity theory. Weyl had "the extraordinary ability . . . to get into a new subject and bring an important contribution to it within a few months." The field of Lie groups was dominated by Cartan (mainly Lie algebras and local groups) and by Schur and Hurwitz, with each side ignoring the work of the other. Weyl learned both sides. He emphasized the global groups and their algebraic topology, and he introduced a new tool: the finite group generated by reflections that we now call Weyl group. He also made an important contribution to the theory of finite dimensional representations of simple Lie groups (including the famous character formula). In the preface of his *Classical Groups, Their Invariants and Representations*, Weyl states: "It is high time for a rejuvenation of the classical invariant theory which has fallen in an almost petrified state." I find Borel's study of Weyl's work on invariant theory, presented in historical perspective and also from a modern point of view, a genuine masterpiece.

One can enjoy these three brilliant lectures just as one enjoys going to a good concert. But if one wants to know more about Weyl's scientific achievements in other domains of research than those dealt with by Borel, one will have to read other contributions celebrating Hermann Weyl. Some of them will undoubtedly come from another centenary celebration, held in Kiel, near Weyl's birthplace.

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Elementary Particle Physics

The Particle Hunters. YUVAL NE'EMAN and YORAM KIRSH. Cambridge University Press, New York, 1986. xii, 272 pp., illus. $49.50; paper, $13.95. Translated from the Hebrew edition (Givatayim, Israel, 1983).

It is a good time for popular accounts of the recent developments in elementary particle physics. The accomplishments of the past two decades have led to a quite concise and unified picture, one that is easily summarized. Nevertheless this synthesis is not easy to appreciate fully without knowing how we got to now from then. And the storyteller has to decide where to begin: when is "then"? Almost invariably the tale begins no later than the end of the last century, if only to introduce the reader to basic concepts of relativity and quantum theory. This book is no exception. Of its 260 or so pages, about one-third are devoted to the oft-told prehistory of Bohr, Einstein, Heisenberg, and their associates. And given this breadth of scope, the writers must opt either for a weighty, comprehensive tome (which this book, mercifully, is not) or selectivity of coverage—or at least of emphasis.

The Particle Hunters emphasizes developments peaking in the early 1960s, culminating in the identification of quarks as basic building blocks of matter. During this period many new states of matter were discovered. They are now interpreted as quantum states of three quarks (baryons) or of a quark and antiquark pair (mesons), analogous to nuclear or atomic levels. The need for their classification and the development of the tools for doing so were paramount. The key was the identification of conservation laws and the symmetries underlying them. A principal tool was the mathematics of Lie groups. And one of the important contributors to all this was Yuval Ne'eman, coauthor of this book. It is no surprise therefore that the chapters dealing with this material are the heart of the book.

The basic format of *The Particle Hunters* is historical narrative. After the aforementioned introductory sector and a sequel on the experimental developments of the prewar and early postwar periods, the authors recount the history of the discovery of strange particles and the hadronic resonances, along with the theoretical response. There is a splendid chapter on symmetries, including the discrete symmetries of parity, charge conjugation, and time reversal, and the discovery of their violation in weak interactions.

Quarks do not arrive on the scene until the last quarter of the book. Thus the developments of the 1970s and early '80s, though adequately covered, get somewhat less emphasis. One consequence of this is that what is to me the climax of the story, the emergence of theories of the forces and their description in terms of the symmetry principle of local gauge invariance, is muted. One feels, instead, the steady but inconclusive progress in penetrating layers of structure of matter, as implied by the present compact, yet uncomfortably large, "periodic table" of quarks, leptons, and force carriers.

An excellent feature of the book is its emphasis on the experimental side of the subject, including the development of particle accelerators. Another is the series of marginal notes, anecdotal in character, that add the all-important human element to the narrative. Ne'eman's own story is there, and an interesting one it is. And in general the coverage of material is complete and accurate. Kirsh is a specialist in popular exposition, and the introduction and management of jargon are skillfully done. The book should be accessible to most readers of this journal. There do exist flaws. For example, the authors fall into the not uncommon trap of asserting that the gluon-mediated strong force between quarks weakens at short distances and grows at long distances. (It is roughly inverse-square at short distances and constant at long distances.) And there is a zinger in their discussion of neutrino physics, where it is claimed that "experiments have been carried out in the United States in an attempt to exploit neutrino beams as a method of communication with submarines. . . . Since this method has only military implications, the results of these investigations are being kept secret." It must be noted that Ne'eman has been deputy director of Israeli intelligence. However, high-energy neutrinos are needed to achieve such communication, and all research with them is unclassified: proposals on neutrino communication have consistently been rejected as unfeasible.

There is a curious omission in the index. The most quoted person in the book is Alfred Nobel. There are at least four dozen references to The Prize in the text but no citation in the back of the book. I would have preferred it the other way around. After all, the unsuspecting reader might get the idea that high-energy physicists feel the real reward for their labors is that trip to Stockholm. That's no reason to build the Superconducting Super Collider.

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Minicourses

Intersection between Elementary Particle Physics and Cosmology. T. PIRAN and S. WEINBERG, Eds. World Scientific, Singapore, 1986 (U.S. distributor, Taylor and Francis, Philadelphia). x, 220 pp., illus. $42. Jerusalem Winter School for Theoretical Physics (Dec. 1983), vol. 1.

Physics in Higher Dimensions. T. PIRAN and S. WEINBERG, Eds. World Scientific, Singapore, 1986 (U.S. distributor, Taylor and Francis, Philadelphia). x, 236 pp., illus. $44. Jerusalem Winter School for Theoretical Physics (Dec. 1984), vol. 2.

The Jerusalem Winter School was first held in December 1983 and has since met annually. Each year a distinguished faculty has been assembled to give a set of intensive minicourses covering an important, rapidly developing area of theoretical physics. By all reports the venture has been outstandingly successful.

The two volumes under review are collections of written versions of lectures given at the first two winter schools.

The first volume deals with the intersection between elementary particle physics and cosmology. This area had an impressive infusion of new ideas in the late 1970s, notably including a possible microphysical