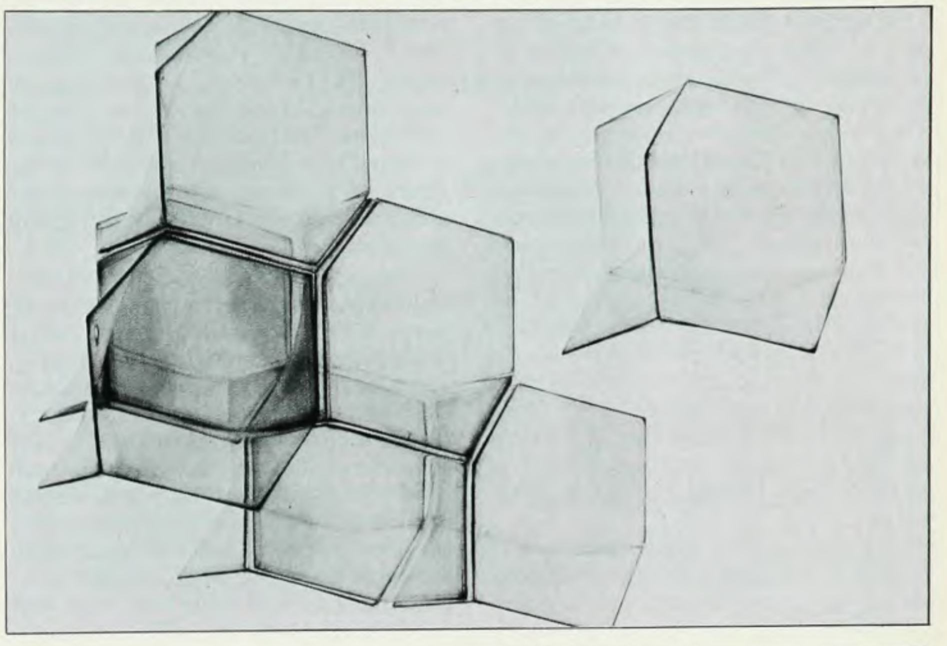
books

Geometric structures: a revival of interest



Three-Dimensional Nets and Polyhedra

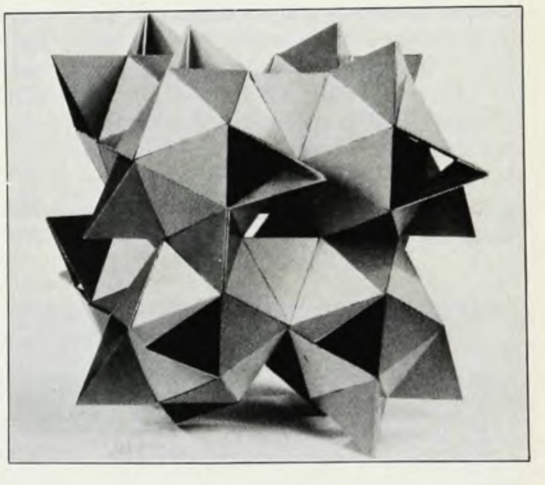
A. F. Wells
268 pp. Wiley-Interscience, New York, 1977
$29.95

Structure in Nature is a Strategy for Design

Peter Pearce
245 pp. MIT Press, Cambridge, 1978
$45.00

Reviewed by Paul J. Shlichta

The study of geometric structures, such as sphere packings and periodic networks, has until recently had somewhat the status of a cult confined mainly to recreational mathematicians and a handful of theoretical crystallographers. Recently, however, the geometric boom in art and design and the use of geometric representations in topics ranging from Fermi surfaces to catastrophe theory has stimulated a widespread revival of interest. It has also become apparent that the discovery of new kinds of geometric structures is by no means over. The present books, for example, deal with structural types that were unknown until a few decades ago and are now appearing in book form for the first time.



Three-dimensional structures. From the two copiously illustrated books reviewed on this page we show (above) Peter Pearce's derivation of diamond lattice as packing of saddle-hexagon tetrahedra and (right) a unit cell of the polyhedral sponge (3, 10)-6t from A. F. Wells's book.

The interpretation of crystal structures as sphere packing dates back to Johannes Kepler and reached its culmination in the predictive successes of modern crystallographers such as Pauling, Laves and Kaspar. In 1954 Alexander F. Wells, already known for his reference compendium *Structural Inorganic Chemistry,* suggested the alternative approach of regarding crystal structures as topological networks. His development of this theme, in a series of twelve papers spanning over twenty years, greatly influenced contemporary crystallographers such as P. B. Moore and J. V. Smith. *Three-Dimensional Nets and Polyhedra* is essentially a revision and expansion of these papers.

The first part describes the derivation of periodic networks in which either all minimum circuits or all nodes are equivalent. Starting with Euler's polyhedron rule, Wells develops a topological-network eigenvalue equation. Then, in what must be the recapitulation of a tremendous effort, he examines each set of possible eigenvalues for geometrically realizable examples. In all, Wells describes over ninety nets; most of these have three to four links per node and are therefore potential covalent crystal structures. In Wells's opinion, many more such nets remain to be discovered.

In the second part Wells uses similar procedures to generate over 65 "three-dimensional polyhedra" (also called skew polyhedra or sponges); these may be thought of as hollow tesselated networks or, equivalently, as multiconnected periodic surfaces that separate space into two interpenetrating labyrinths. Wells's work represents the first major advance in the study of these remarkable structures since Coxeter reported the first three examples in 1937. Other chapters consider related topics such as interpenetrating networks and edge-sharing octahedral assemblages.

The book is intended as an advanced monograph for specialists and, although clearly written, demands careful attention from the reader. Novices may require a preparatory test such as the author's own *Third Dimension in Chemistry* or Arthur Loeb's *Space Structures: Their Harmony and Counterpoint* (see PHYSICS TODAY February 1977, page 56). The profuse illustrations, many of them stereographic pairs, are frequently fascinating, but in some cases are inadequate or obscurely complex. Wells lists relevant crystal structures in a separate index, but there is a lamentable absence of any overall tabulation of the networks and their geometric parameters. In short, this is a brilliant book, but not an easy one from which to extract information.

In contrast, Peter Pearce in his *Structure in Nature is a Strategy for Design* makes every effort to make perusal of his book easy for the inexperienced reader. This is in keeping with his aim of presenting to the general public his theories on structural design. Pearce's approach emphasizes the use of geodesic surfaces, usually single or multiple saddles, whose joints lie parallel to cubic symmetry axes. Pearce has already demonstrated his concepts through the toys and playground structures manufactured by Synestructics Inc.; his book is directed toward their application in architecture. Like Wells, however, Pearce devotes most of the book to the derivation and description of hitherto unpublished geometric structures.

The book opens with introductory chapters on physical and biological structures in nature, structural rigidity, symmetry, and on known geometric structures such as planar tilings, polyhedra packings and networks. In the second section, Pearce demonstrates that periodic network circuits define the boundaries of geodesic saddle surfaces and therefore correspond to packings of curved-face polyhedra. He then describes and tabulates the properties of 53 saddle-faced polyhedra, 42 corresponding space-filling packings and 14 curved-surface "labyrinths" (three-dimensional polyhedra in Wells's terminology). The third section examines some useful geometric properties of these structures, such as triangulation of continuous-curved surfaces, open polyhedra packings, and the generation of finite polyhedral clusters with potential internal diversity. The fourth section discusses architectural applications.

The book is easy to read and offers many plausible and original geometric ideas. It is lavishly illustrated and contains many useful tables listing the structures and their geometric parameters. Its chief shortcoming, from a physicist's viewpoint, is the lack of mathematical content. Pearce gives no topological derivations (Euler's rule is confined to a footnote) and ignores the symmetry properties of the structures (for example, their definitions in space-group notation).

The relevance of these books to crystallography and architecture is fairly obvious; their value for physicists in other fields largely remains to be demonstrated. The relation of the labyrinth structures to heat exchangers and honeycomb fabrication is immediately apparent. Some of the networks bear enough resemblance to Michell's optimum strength/weight frameworks to recommend them for consideration in aerospace and solar-array extended-structure applications. Integrated-circuit architects may well find inspiration in some of the high-connectivity nets. In summary, few physicists will feel obliged to study these books in detail, but many will find a brief examination stimulating and rewarding.

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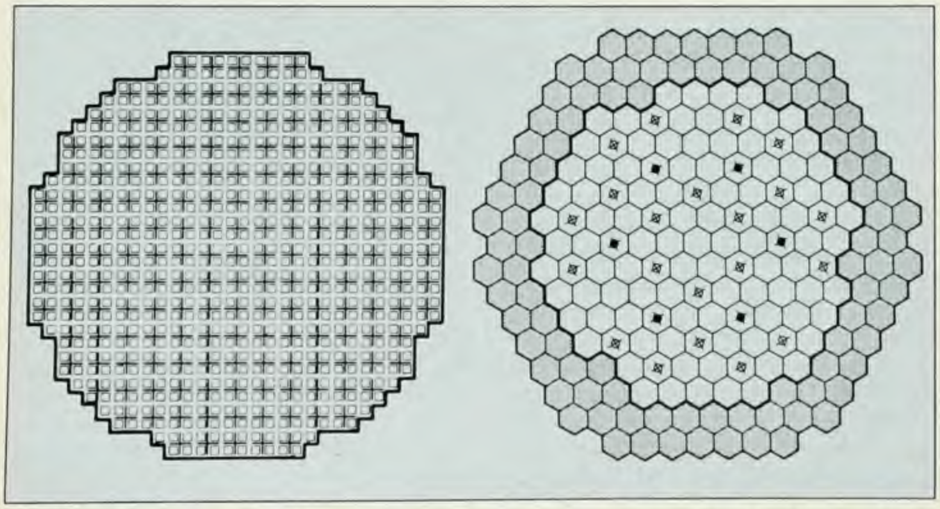

Control rods are used in nuclear power reactor cores to compensate for fuel depletion and temperature effects as well as to execute changes in power level and to shut down the reactor. Because the control rod is effective over only a short distance, a substantial number of them must be distributed uniformly through the core. Shown above are control-rod arrays for a boiling-water reactor (left) and a gas-cooled fast breeder (right). (From E. E. Lewis's book reviewed here)

Nuclear Power Reactor Safety

E. E. Lewis
630 pp. Wiley-Interscience, New York, 1977. $32.00

Nuclear reactor safety is a highly politicized subject, on which passions run high, so that it is a pleasure to see a book that simply contains an enormous amount of technical information about the behavior of reactors in upset conditions, and grinds no visible axes. *Nuclear Power Reactor Safety*, by Elmer Eugene Lewis of Northwestern University (no relationship to the reviewer), is just what the title implies. It is a book that leads the reader through a rather detailed quantitative discussion of the design and operation of reactors, through a treatment of the role of quantitative risk assessment, reliability and such things, to a detailed assessment of the various mishaps that can befall a reactor. The latter include transients, fuel element failures and loss-of-coolant accidents. Finally there is a long discussion of containment, and of the consequences of an accident. The book is complete and informative on the subject of technical reactor safety, and is even sound on the more elusive subjects, such as licensing, redundancy, and reliability.

One subject not covered at all in the book, perhaps through a wise choice on the part of the author, is probabilistic safety analysis—the effort to quantify the probability of malfunction of a reactor. The Reactor Safety Study issued by the Nuclear Regulatory Commission in 1975 was a major effort to do just that, and Lewis extensively uses it and its draft version as references in the book. He uses it, however, only as a source of technical information on reactors, rather than for its major content, the calculation of the probability of a core melt. While the results of that calculation in the Reactor Safety Study leave something to be desired, the methodology involved—the quantitative evaluation of the probability of different upset sequences in a reactor—can become a very powerful tool for the rationalization of nuclear safety assessment. The Nuclear Regulatory Commission has only recently issued a policy statement committing itself and its staff to wider application of these procedures in the regulation of the nuclear industry.

This is only a small cavil, because a proper treatment of probabilistic risk assessment would entail a separate book by itself, and its omission does not detract in any way from the usefulness of this book. It is clearly the place of choice to