audible to musicians at the center of the stage, which was due to a movie-projection booth with an improperly designed front that was added without my prior knowledge. A sound-diffusing structure planned for the side walls (similar to the quadratic-residue diffuser described by Schroeder) was eliminated by the owner.

The hall opened to loud complaints, only some of which were based on its acoustics. The owner engaged a committee of four, who worked for two summers. Their efforts must also have been frustrated by some of the same political factors. Finally the owners engaged another acoustical consultant and a new architect. Their design, which was implemented, was almost identical to that proposed by me, but with a somewhat shorter reverberation time.

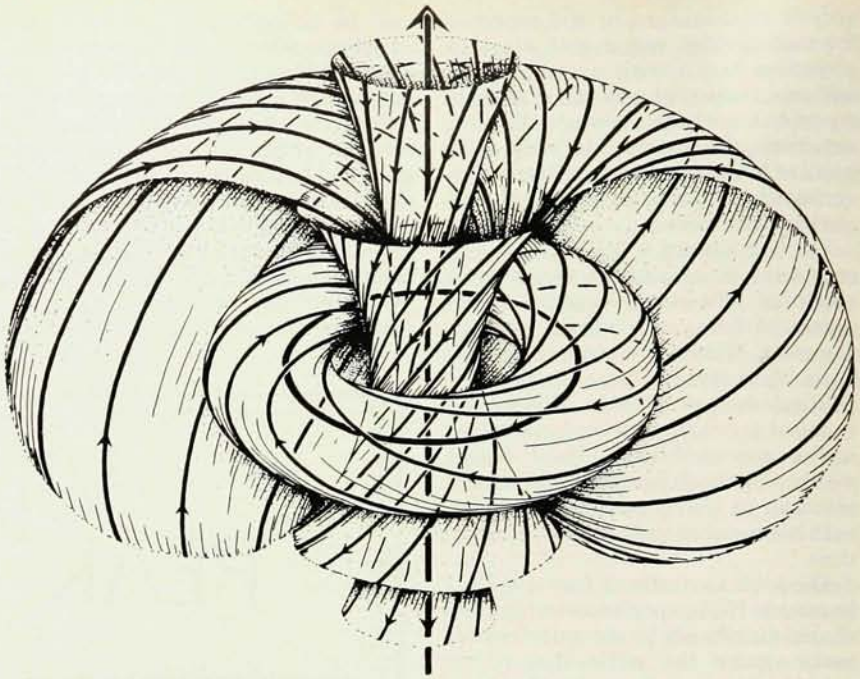
The trauma resulting from the Philharmonic Hall experience—which was shared vicariously by acoustical consultants around the world—has in the past 24 years led to the first real experimental laboratory research on concert-hall acoustics since Sabine's work. Ando's book is the most recent summary of these efforts. I hope that halls of the future will continue to benefit from these new approaches. Certainly, Ando's book is a vital contribution and deserves the fullest attention of the profession.

Spinors and Space–Time, Volume 2: Spinor and Twistor Methods in Space–Time Geometry

Roger Penrose and Wolfgang Rindler
501 pp. Cambridge U.P., New York, 1986. $89.50

Unlike volume 1, much of which could have been written 15 years ago, most of the material in volume 2 of *Spinors and Space–Time* is current. About half of the references are to work after 1975 and many of these are to work after 1980. Indeed, this is a book which is looking ahead. While these two volumes record a large amount of completed work, they are part of a continuing program to develop a new theory of space–time in which the points of the manifold are not the primary objects. In this way one hopes to get around the difficulty in a quantum theory of gravity caused by the need to define fields on a manifold. Twistors form the the basic geometrical entities in that endeavor. However, while twistors are introduced in this volume and their use forms a large part of it, they are used here only to elucidate known results or to develop new results in conventional field theory.

The fact that this can be done with a certain elegance suggests that twistors may be an appropriate tool for constructing a generalized theory of space–time. However, the possible generalizations are only hinted at. The hints come from the definition of fields by contour integrals in projective twistor space, which leads to the use of sheaf theory and cohomology; the recognition of twistors and dual twistors as canonical conjugate variables; the very brief description of H-spaces and their relation to asymptotic twistors; and occasional references to work "beyond the scope of these volumes" such as that on the nonlinear graviton. As a result, this book is an introduction to twistors and their application to a number of well-known problems that have been or could be solved in other ways. The success of the twistor program up to the points discussed in this volume is tantalizing. It suggests that the power of the methods will be important in the development of future physical theories. One problem I see, however, is that the program is being carried out mostly by



The projection of a Robinson congruence into a Euclidean three-space. This figure, drawn by Penrose, is reprinted from the book under review.

people who are mathematically rather than physically motivated, so that the connections with physics may follow developments in other areas, rather than lead them.

Volume 1 of *Spinors and Space–Time* (see PHYSICS TODAY, February, page 86) introduces spinors as the fundamental geometric entities on a manifold out of which tensors may be constructed. Many of the results of differential geometry have a simpler or more transparent structure in terms of spinors than in the classical presentation. With a marvelous sense of consideration for their readers, the authors begin this volume with a 42-page summary of volume 1. Any equation in that volume to which reference is made appears in the summary. Only two or three figures of interest have been omitted.

Volume 2 introduces twistors, with their particular relation to Minkowski space, through the twistor equation and its generalization to twistors of higher rank. A null twistor has the representation of a null geodesic in Minkowski space. A non-null twistor has its representation in terms of a congruence of shear-free twisting null rays—a Robinson congruence. This, we are told, is the origin of the name "twistor." Applications of twistors, however, are not restricted to fields in Minkowski space.

Perhaps the one concept that is ubiquitous in the volume is conformal invariance. It arises in the discussions of massless fields, of the conformal compactification of Minkowski space, and of the 4:1 homomorphism between SU(2,2) and C(1,3)—the transformation group for twistor space and the conformal transformations on Minkowski space. Much beautiful geometry is involved in these discussions, but the goal is to provide a description of massless fields. In fact, the last 100 pages of the final chapter are concerned with this topic. Most of the results on conformal invariance have already appeared in the literature. This is particularly true for the Weyl tensor and spin coefficients of the gravitational field. However, the presentation here has a coherence that others lack, because of the completeness of the treatment.

The concepts of energy–momentum and angular momentum occupy a large part of this book. The discussion begins early in the book with the construction of the angular-momentum twistor (which also contains the 4-momentum) for a particle in Minkowski space. This is extended to massless fields and finally to general relativity. In the final chapter quasilocal quantities are defined in curved space–time with the help of two-surface twistors, which satisfy a projected twistor equation. The authors discuss these interesting quantities in considerable detail, carefully pointing out the difficulties as well as the advantages, with ample reference to the literature. The main body of the book concludes with a description of the Bondi mass loss and the very important proof of the positivity of the Bondi mass.

Throughout, the book alternates between a straightforward application

of spinor analysis and the application of twistor techniques.

The organization of the book is excellent. Penrose and Rindler present the important results on the use of spinors in general relativity and in the study of the structure and properties of asymptotically flat space–times side by side with those on the use of the twistor formalism in describing space–time geometry and fields on that geometry. Therefore, for those to whom the subject is new, a guide through the book would have been useful. In the preface, the authors indicate that Chapter 8 can be read independently. However, the first three sections of Chapter 7 form an introduction to that material. Also, much of Chapter 9 can be read before becoming involved with twistor theory. I don't mean to imply that the purely spinorial material should have been separated from the twistor applications—such an approach would have destroyed the coherence of the presentation noted earlier.

Although this volume makes use of the algebraic techniques and results of volume 1, geometrical ideas are emphasized throughout. There are more of Penrose's carefully drawn figures and this time they are more or less uniformly distributed. The volume also has an excellent index and list of references. In the appendix, the authors present a useful description of spinors in n-dimensional space.

Whether or not twistors ultimately live up to Penrose and Rindler's expectations, there is no doubt that the material in these two volumes will continue to be studied for many years and will lead to new results in differential geometry, general relativity and other parts of physics.

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General Biophysics, Volumes I and II

M. V. Volkenstein
(Translated from the Russian by I. C. Melamed and M. V. Volkenstein)
302 + 314 pp. Academic Press, 1983. Vol. I. $61.00, Vol. II. $51.00

The late George Gamow once said that he dreaded the day when physics would leave the era of Columbus and Magellan and enter into the era of *National Geographic*. No biophysicist need have such fears yet, and indeed, in his later years, even Gamow made contributions to this field.

Biophysics is the physics of biological phenomena; it is not an auxiliary to the fields of biology and physiology. The phenomena are considered at three levels, the macroscopic, the microscopic and the molecular, and while the research interests of individual investiga-