FRANK ARMSTRONG

PRIGOGINE

librium phase transitions, time-symmetry breaking and other critical oscillatory fluctuations.

This is an imaginative and provocative work that surely will stimulate lively scientific and philosophical debates for years to come. With great skill, clarity, mathematical and pictorial elegance, and with considerable persuasion, Prigogine explores and deepens some of his earlier ideas, now placed within a much broader spectrum of problems. Included are numerous pertinent discussions of oscillating systems composed of nonlinear differential equations and complicated processes involving the self-organization of systems: chemical kinetics in far-from-equilibrium reactions, thermal diffusion, the patterns of circulation in planetary atmospheres, fluctuations in the way a given ecological niche is understood to be exploited, the growth of populations and towns, oscillations in enzyme activity in metabolism, the movement of monocellular organisms from nutrient-poor to nutrient-rich media, the process of replication of polymers, cross-catalytic mechanisms, regulatory processes at the cellular level, and the aggregation process in slime mold formation.

The author's analysis demonstrates that the idea of time asymmetry stands in need of a radical reappraisal, not only in thermodynamics proper but also in relation to "the baroque of the natural world" and to complicated artificial systems and ecosystems. Prigogine explicitly emphasizes that his intention is not to reduce physics and biology to a single scheme but to define clearly the various levels of description and to present conditions that permit us to pass from one level to another.

Throughout this work Prigogine has accentuated the fact that we are living in a single world whose aspects, however diverse they may seem, must bear some phenomenological relation to one another. In many areas of the sciences no notable progress in the direction of reductionist unified theories has been accomplished. He writes: "The world is richer than it is possible to express in any single language. . . .Scientific work consists of elective exploration rather than a discovery of a given reality; it consists of choosing the problem that must be posed."

Accordingly, the problem of constructing a bridge from "being" to "becoming" is seen by Prigogine to be crucial. His solution is to introduce the formal device of a microscopic entropy operator that corresponds to unobservable idealizations. Further, his objective is to demonstrate how the usual formulation of classical or quantum mechanics becomes "embedded" in the larger theoretical structure that allows for the description of irreversible processes. Thus irreversibility becomes not some approximation added to the laws of dynamics but the focus for an enlargement of the theoretical structure.

Prigogine obviously is strongly attracted to a pluralism of scientific schemes in looking at the nature of things; in this case, in fact, to a complementarity between dynamical frameworks, where $t \longleftrightarrow -t$ holds, and in thermodynamic frameworks, where $t \longleftrightarrow -t$ is incorporated into the conceptual structure. According to Prigogine, both are equally fundamental and merit equal theoretical status. He concludes:

> *A posteriori*, it is difficult to imagine how the conflict between "being and becoming" could have been resolved in a different way. In the nineteenth century, there was a profusion of controversy between "energeticists" and "atomists," the former claiming that the second law destroys the mechanical conception of the universe, the latter that the second law could be reconciled with dynamics at the price of some "additional assumptions" such as probabilistic arguments. What this means exactly can now be seen more clearly. The "price" is not small because it involves a far-reaching modification of the structure of dynamics.

ERWIN N. HIEBERT
Harvard University

Elements of Acoustics

S. Temkin
Wiley, New York, 1981. $27.95

Students of acoustics at the beginning graduate level will benefit greatly from this new text, derived from a course in acoustics taught for several years at Rutgers University by Samuel Temkin. Treating acoustics as a branch of fluid mechanics, he describes waves in fluids and gases, but not in solids. With this emphasis he presents a detailed treatment of sound absorption in fluid media, a subject to which he has made several important research contributions.

The emphasis of the book is on theory. Once he derives the wave equation, Temkin gives many examples of its solutions to boundary-value problems. Although this technique allows the analyst to recover the waveforms of all acoustical variables at all points within the boundary, only simple situations can be treated in this analytical way. However, acoustics is mostly an applied science, in which measurements are commonly required. An experimenter can seldom use the precision of a waveform if it requires a separable coordinate system. In fact, often the only interesting measure of a waveform that is of first order in the amplitude is the amplitude density distribution. More commonly needed are its quadratic measures, such as power, power spectral density and covariance. Sometimes fourth-order measures of a waveform are necessary to reveal the properties of an acoustical propagation path. Measurement and prediction of these "measurable" properties of acoustical waveforms are not subjects common in fluid mechanics, while they are in electrical engineering, for example. After a study of the "physics of sound," guided by this book, a student would need to study the "signals of sound" guided, for example, by the *Foundations of Acoustics* by Eugen Skudrzyk.

The first two chapters present an exceptionally clear basis for wave motion in fluids. Except for the lack of a generalization to solids, the first chapter is a clear statement of continuum mechanics. The author takes care to include body forces and both conservative and dissipative terms in the equations of motion, in order to establish foundations for later studies of the effects of viscosity and heat transfer.

The third and fourth chapters are an analytical exposition of wave propagation, including plane, spherical and cylindrical standing and free waves. Temkin also includes wave transmissions through plane interfaces, two- and three-dimensional waveguides, and horns. Befitting the foundations he established in the first two chapters, he covers very efficiently both waveform distortion and attenuation owing to finite amplitudes. In keeping with his emphasis on exact solutions to the wave equation, he omits high-frequency asymptotic solutions, such as optical diffraction theory or the Eikonal equation, even though these "ray theories" are very important to applications of acoustics.

The fifth chapter deals with sound

radiation in a very comprehensive way. It begins with a detailed examination of the simple source and continues with the integral equations for radiation from distributions of dipoles and quadrupoles. The source distributions are taken to be deterministic in space and time; Temkin does not treat the ensemble averages of spatial source distributions necessary to compute noise power radiated by turbulence. The book's treatment of sound emission by heat release will be useful to researchers using lasers as "steerable" sound source arrays. A shortcoming, however, is the neglect of electroacoustics, the phenomenon responsible for generating most of the volume velocities and forces that cause the sound waves we study.

The final chapter on sound absorption contains the most comprehensive treatment I have seen in a textbook on absorption of sound in gases. Temkin treats both viscosity and heat conduction theoretically and includes measurement results to demonstrate their separate contributions to absorption. He demonstrates clearly the concept and effects of relaxation, but omits the relaxation effects of chemical reactions, which are, however, more important in liquids than in gases.

This text establishes a broad and clear foundation for the physical nature of wave generation and propagation in fluids. It provides a good basis for beginning study in acoustics.

JAMES E. BARGER
Bolt Beranek and Newman Inc.

The Quest for Extraterrestrial Life: A Book of Readings

D. Goldsmith, ed.
308 pp. University Science Books, Mill Valley, Ca., 1980. $18.00 cloth, $12.00 paper

Strategies for the Search for Life in the Universe

M. D. Papagiannis, ed.
253 pp. Reidel, Dordrecht, Holland, 1980. $30.00

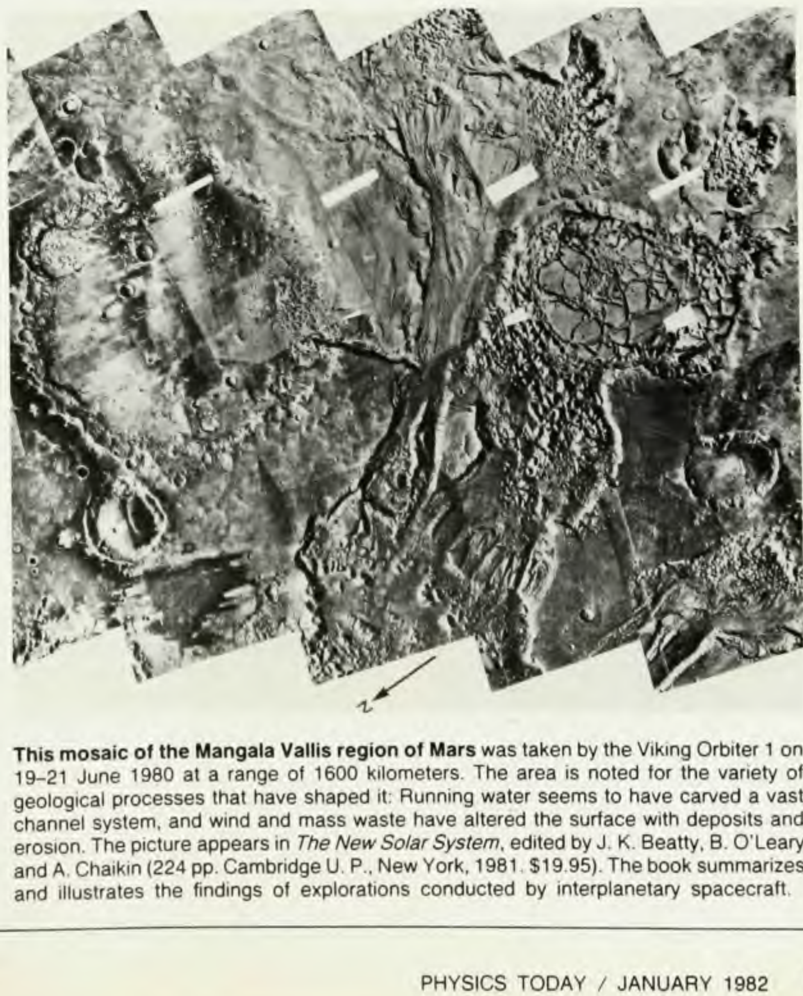
Life beyond Earth: The Intelligent Earthling's Guide to Life in the Universe

G. Feinberg, R. Shapiro, eds.
464 pp. Morrow, New York, 1980. $9.95

The three books listed above demonstrate that neither has the deluge of publications in the debate on extraterrestial life diminished nor has their diversity decreased. That diversity is especially well illustrated by *The Quest for Extraterrestrial Life: A Book of Readings*, edited by Donald Goldsmith, a California astronomer. Consisting of 58 selections chosen from the writings of authors as ancient as Lucretius and as contemporary as Gerald O'Neill and Carl Sagan, Goldsmith's anthology concentrates on the period after 1959, in which year Giuseppe Cocconi and Philip Morrison proposed using the 21-cm radio emission line of neutral hydrogen as the most natural and appropriate wavelength at which to seek signals from extraterrestrials. Their paper on the "water hole" of the universe helped unleash widespread interest in this topic, which from about 1920 to 1950 had fallen from favor because of the prevalence of encounter theories of planetary formation that predicted a planet-poor universe and also because of the excesses of the champions of a canaled Mars. Goldsmith's nine selections from pre-1910 publications, some translated specifically for this volume, remind us that the debate is one of longstanding interest and seems—even now, despite the progress of twentieth century astronomy—far from resolution.

Although Goldsmith's editorial apparatus is sparse, the wide array of methodologies and positions represented in his anthology, as well as their judicious balance, shows the presence of an active editor concerned with informing rather than propagandizing. John Ball and Ronald Bracewell, Frank Drake and Freeman Dyson, Michael Hart, Norman Horowitz, and Fred Hoyle, Carl Sagan and George Simpson are all among the anthologized authors, who in nearly every instance are scientists of prominence. Goldsmith's collection is sufficiently current to catch the wave of scepticism that came in the late 1970s following the seemingly negative results of the Viking missions and Michael Hart's 1975 paper urging that the absence of visits of extraterrestrials from the solar system combines with the apparent feasibility of interstellar travel by advanced civilizations to suggest that the number N of advanced civilizations in our galaxy may be very small. This position, developed by Frank J. Tipler in the April 1981 issue of PHYSICS TODAY, is now being taken seriously even by advocates of high values of N. Persons new to the field will find this book an excellent introduction, whereas persons who read many of these papers upon their first appearance will be happy to find them collected into a handsome, large volume that includes a useful bibliography.

The diversity in the debate is differ-



This mosaic of the Mangala Vallis region of Mars was taken by the Viking Orbiter 1 on 19–21 June 1980 at a range of 1600 kilometers. The area is noted for the variety of geological processes that have shaped it: Running water seems to have carved a vast channel system, and wind and mass waste have altered the surface with deposits and erosion. The picture appears in *The New Solar System*, edited by J. K. Beatty, B. O'Leary and A. Chaikin (224 pp. Cambridge U. P., New York, 1981. $19.95). The book summarizes and illustrates the findings of explorations conducted by interplanetary spacecraft.