BOOKS: THEORETICAL BIOLOGY

Structuring Nurture

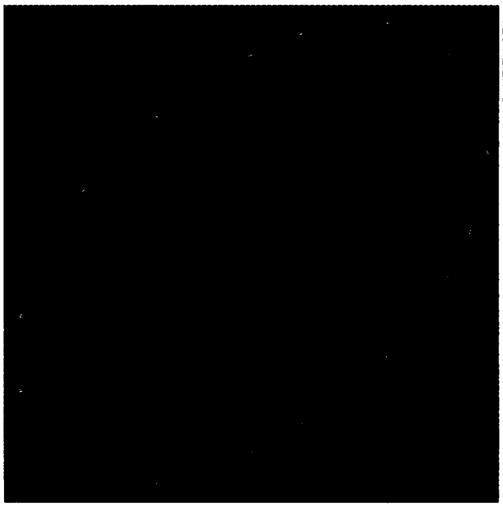
Sunetra Gupta

Life's Other Secret. The New Mathematics of the Living World. IAN STEWART. Wiley, New York, 1998. xiv, 285 pp., illus, + plates. $24.95 or C$34.95. ISBN 0-471-15845-3.

An apparent tug-of-war between "genetics" and "mathematics" forms the template for this fascinating exposition of how simple rules may suffice in generating many of the complex patterns of life as we know it. The spontaneous self-organization of physical material into a multitude of forms is as essential to life, Stewart argues, as the genetic code that underlies it. The author thus offers us an alternative to the notion that genes are engaged in a constant struggle to impose order on a relatively nonparticipatory (and generally unruly) physical universe—with the sole aim of ensuring that their copies survive through time. Instead, he contends, genes act in synergism with the fundamental laws of physical systems to create and maintain viable, flexible patterns. Nurture, in other words, is no less structured than nature, and Stewart steers us expertly through a series of beautiful examples from both the plant and animal kingdoms to prove his point.

Clues to this "second secret of life" are evident in everything from the startling geometry of viruses to the regularities of animal locomotion, and most obviously in the intriguing symmetries of the plant world. Stewart shows how mathematics plays a vital role not only in helping us to understand and catalog these patterns, but also by providing metaphors for the processes that govern them. For instance, drops of magnetic fluid, when allowed to fall at regular intervals into a dish of silicone oil in a magnetic field, will with a high probability arrange themselves into "sunflower seed patterns of interlaced spirals." By investigating the properties of this physical analog, insights can be gained into the fundamental rules of plant growth.

Stewart, a professor at Warwick University and the author of many popular books on mathematics and its applications, should have no problem convincing his readers that mathematics is the appropriate language for exploring how the spontaneous behavior of inert physical systems has been marshaled by genes into supporting vital processes. But he unnecessarily belabors the point that genetics is not the "only secret of life"—that DNA by itself in a test tube "won't come to life." There is no real controversy here—it is not difficult to reconcile genetics with mathematics. Stewart does so himself, for example, in analyzing the mystery of collective behavior in animals: "There is—I strongly suspect—no genetic instruction to 'form a flock' in a bird. Instead, there are genetic and behavioral analogues of the rules that produce flocks."



G. KEITH STILL

Geometry of motion. An orchid fractal, produced by modeling crowd flow.

Rather than providing explicit instructions, DNA works by setting out the rules that, within the context of the laws embedded within material systems, can produce complex organisms with intriguing social behaviors. This does not mean, however, that we should stop holding genes responsible for these life processes and abandon our search for genetic associations with certain traits, as Stewart appears to suggest. What makes someone thin or homosexual may be neither straightforward nor particularly useful to know, but whether a gene confers resistance to a disease can be a critical piece of information in the design of drugs and vaccines.

The unnecessary polarization of genetics and mathematics as a framework for the book does little justice to its content. Mathematics is an important and exciting tool for unraveling the mysteries of life; genetics is, after all, just another of these mysteries.

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MICROBES AND MINERALS

Rock and the Role of Microbiology

Derek R. Lovley

Geomicrobiology: Interactions Between Microbes and Minerals. JILLIAN F. BANFIELD and KENNETH H. NEALSON, Eds. Mineralogical Society of America, Washington, DC, 1997. xvi, 448 pp., illus. Paper, $32. ISBN 0-939950-45-6. Reviews in Mineralogy, vol. 35.

"These are good times to be a geomicrobiologist!" This exclamation in a chapter by W. W. Barker, S. A. Welch, and J. F. Banfield captures the spirited tone of this timely volume of *Reviews in Mineralogy*. *Geomicrobiology: Interactions Between Microbes and Minerals* is the product of a diverse group of internationally recognized geochemists and microbiologists that participated in an interdisciplinary Short Course on Geomicrobiology presented last year by the Mineralogical Society of America. Recent advances in microbiological and geochemical techniques make it likely that, as Barker *et al.* suggest, we are indeed entering "the golden age of geomicrobiology." This book provides enough introductory material to serve as a primer for novices interested in taking a first look at this rapidly emerging field, as well as sufficient detail and new insights to provide a handy reference for researchers already actively mining this area.

Decades of intense study have revealed many of the mechanisms by which microorganisms interact with organic compounds in the environment. In contrast, despite several hundred years of investigation in the fields of geology and microbiology, the role of microorganisms in the formation and dissolution of inorganic minerals is poorly understood. One reason for this lack of knowledge is that scientists trained in microbiology rarely have any significant training in geology and vice versa. Such cross-training is necessary if we are to

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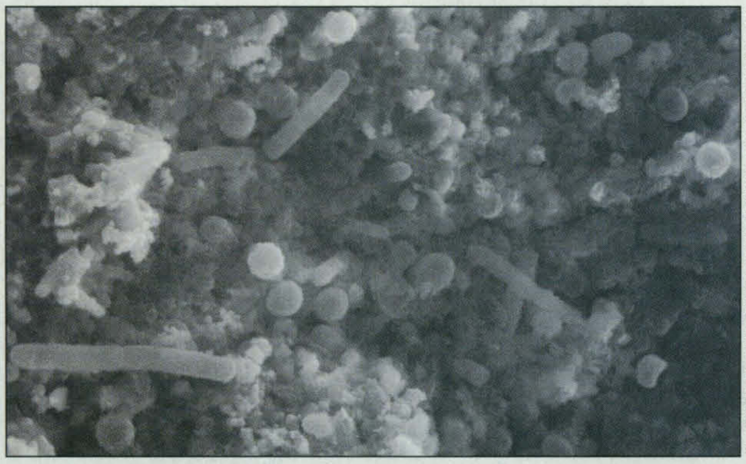
find solutions to important societal concerns such as deterioration of groundwater quality, environmental contamination, the loss of productive agricultural lands, and global warming. Another inducement to increase our understanding of microbe-mineral interactions has been the realization that a large proportion of the yet unexplored biota on Earth, and possibly that on other planets, probably derives a living from reactions that either produce or consume minerals. This book emphasizes that a concerted interdisciplinary effort of geochemists and microbiologists will be required both to determine which microbe-mineral interactions are environmentally significant and to define the biochemical and geochemical controls on these processes.

For the non-microbiologist, the first two chapters of the book provide an overview of the physiological and phylogenetic diversity of microorganisms. Both chapters stress how the study of 16S ribosomal RNA sequences recovered from various environments has revealed a wide diversity of microorganisms that have not been previously cultured—a common theme in modern microbial ecology. Unfortunately, the 16S ribosomal RNA approach reveals little about the reactions that these phylogenetically diverse microorganisms are executing in the environment. Therefore, it is refreshing to see emphasized several times throughout this book the need for environmental microbiologists to move beyond descriptive phylogenetic surveys and to make renewed efforts to culture novel microorganisms—so that their biogeochemical capabilities can be investigated. In this regard, geochemists can help microbiologists by elucidating geochemically significant reactions that microbes might be applying to promote their growth.

For the geochemically challenged, the book contains excellent descriptions of mineral structure and surface chemistry as well as chapters on the mechanisms by which microorganisms or their extracellular products may react with these mineral surfaces. Photomicrographs and diagrams greatly facilitate visualization of the phenomena discussed.

Several chapters give specific examples of biomineralization and mineral dissolution. These include a fine summary of the current understanding of the formation of magnetite by magnetotactic bacteria. This is one of the best studied examples of biomineralization by bacteria and provides an excellent illustration of how microbial activity can leave a distinct geologic signature—in this instance, ultrafine-grain magnetite particles with unique shapes and magnetic properties. Another chapter describes how the adsorption of minerals onto microbial surfaces can lead not only to mineral deposition but also to the fossilization of microbes, providing a clear record that microbes were present in an environment. There are also comprehensive reviews on microbial formation of manganese oxides and the dissolution of iron, sulfur, and silicate minerals, as well as a picturesque and informative description of how algae deposit carbonates and silicates.


B. J. LITTLE, P. A. WAGNER, Z. LEWANDOWSKI, IN *GEOMICROBIOLOGY*

Life in biofilms. Sulfate-reducing bacteria within corrosion products on copper-containing foil.

One disappointment was the rather unbalanced discussion of microbial interaction with toxic metals and metalloids. The biochemistry and genetics of microbial resistance to heavy metals are thoroughly summarized, but these resistance mechanisms generally do not contribute to mineral formation and dissolution. Not discussed are recent studies demonstrating that microbes may conserve energy to support their growth by transferring electrons to a wide range of contaminant metals and metalloids such as uranium, technetium, plutonium, chromium, selenium, and arsenic. This metabolism can result in sequestration of the metals in the form of insoluble minerals, or in dissolution of minerals with the release of the toxicants into the environment.

The final chapter illustrates how the isotopic composition of carbon and sulfur deposited in minerals can help elucidate the microbiological activity likely to have taken place in ancient sediments as life evolved. It seems likely that further investigation into microbe-mineral interactions will provide additional geochemical signatures that can be used for detecting which types of microbial activity were important not only on ancient Earth, but in other poorly understood and difficult to sample environments—such as the deep terrestrial subsurface and other planets. Other conceivable benefits from the study of microbe-mineral interactions include a better understanding of the conditions that result in the precipitation of economically important minerals and new strategies for the remediation of environments contaminated with toxic metals. This book should stimulate interest and, hopefully, some innovative thinking in these areas.

Vignettes

Technothought

When I am invited to speak publicly, I often make a point of asking how many people have had nightmares about nuclear war. If I poll members of peace groups, often about two-thirds of the audience raise their hands. In a group of about twenty citizens at a church in Livermore, no hands were raised. When I once asked a group of about seventy laboratory employees, two raised their hands. One scientist once told me, "It's not rational to have nightmares about nuclear weapons. There's nothing you can do about them."

—*Hugh Gusterson*, in *Nuclear Rites: A Weapons Laboratory at the End of the Cold War* (University of California Press)

In 1980, NASA established a Self-Reproducing Systems Concept Team to explore the possibilities of self-reproducing factories. Their aim was to examine the feasibility of devising machines capable of production, replication, growth, self-repair, and evolution, machines that could be used to colonize the moon and beyond. ... As team leader Richard Laing recalled, "There was the suggestion, if you could just tease money for this self-replicating factory, you would never need money again. You could take over the universe."

—*David F. Noble*, in *The Religion of Technology: The Divinity of Man and the Spirit of Invention* (Knopf)