

must be represented solely in terms of nonlocal fields that are nonsingular everywhere, with all mapped in the same space-time. In this way, both $g_{\mu\nu}$ and $T_{\mu\nu}$ are represented by "regular" fields, and the formalism of general relativity becomes fully covariant, characterized by nonlinear space-time transformations.

Summing up this book of correspondence, it is an excellent presentation of "Einstein the scientist" and "Einstein the man." I highly recommend it for all physicists and for historians and philosophers of physics. I have only two negative comments. First, there is a multitude of footnote references throughout the text but, as indicated above, the footnotes themselves were not included in this translated volume. These footnotes are given, in English, in the original version of the book. Second, there is no index for the book. These deficiencies are, nonetheless, far outweighed by the positive aspects of the book.

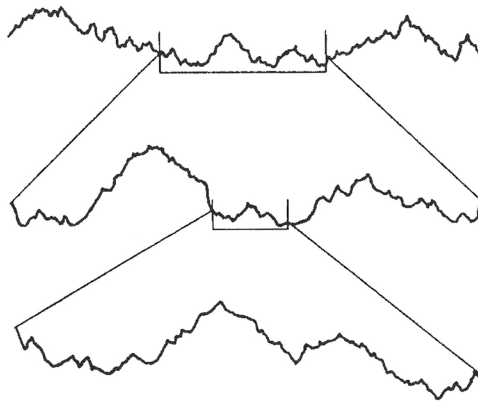
Fractal Physiology

J. B. Bassingthwaighe, L. S. Liebovitch and B. J. West
Oxford U. P., New York, 1994.
364 pp. \$55.00 hc
ISBN 0-19-508013-0

Since the pioneering work of Hermann von Helmholtz, it has been the dream of many a physicist to make a significant contribution to physiology. Therefore, it is with some excitement that one opens *Fractal Physiology*—hoping that this relatively slim monograph might illuminate a path for statistical physicists to follow if they dream of uncovering some of the general physical principles that must certainly underlie even as complex a discipline as physiology.

But wait a minute! What have fractals to do with physiology? Quite a bit, one soon realizes, on reading *Fractal Physiology*. The book begins with an impressive list of biological systems that either are self-similar in space or time or are self-similar in a rather abstract sense that has nothing to do with the object itself, but rather has to do with some property of the object that is mapped onto a genuinely fractal object. An example of the latter category is shown in the accompanying figure. Here is shown the informational content of DNA—its sequence of base pairs—represented graphically, and it is the graphical representation, not the DNA itself, that is statistically self-similar.

After a short overview, which includes a brief section bearing the intriguing title "The Meaning of Fractals," the



A REPRESENTATION of the sequence of base pairs on noncoding DNA in which an "up" step corresponds to one type of base pair and a "down" step to another type. The statistical properties are the same at three different length scales, implying that this representation has useful scaling properties. (Courtesy of Sergey V. Buldyrev.)

authors, J. B. Bassingthwaighe, L. S. Liebovitch and B. J. West, set out, in six well-organized chapters, the general principles of fractal science. This work nicely complements the somewhat more mathematical treatments found in the classic monographs by Jens Feder, *Fractals* (Plenum, 1988) and by Tamás Vicsek, *Fractal Growth Phenomena, second edition* (World Scientific, 1992), and it is more accessible than the widely quoted "essay" of Benoit Mandelbrot, *Fractal Geometry of Nature* (Freeman, 1982). Particularly welcome features are the careful distinction between fractals and chaos, two topics that are sometimes referred to as if they were synonymous, and the lovely description of fractal time concepts pioneered by Michael F. Shlesinger and his collaborators (PHYSICS TODAY, January 1991, page 26). Also well explained are practical procedures used to extract the various fractal parameters that characterize a given set of experimental data.

Fractal Physiology's final chapters deal with a potpourri of applications of fractal concepts to specific topics of interest in physiology. Some of these topics correspond to areas in which one or another of the authors has made major contributions. For example, there is an entire, self-contained chapter on the analysis of experimental data on the opening and closing of ion channels in membranes. Here fractal analysis is systematically compared to the more conventional Markovian models, and analogies are drawn to the dichotomy between Copernicus and Ptolemy.

Another quite readable chapter on fractals in nerves correctly notes that not one but rather many fractal dimensions will sometimes be required to dis-

tinguish among different physiological forms. And the concluding chapter concerns topics on which current research is just beginning, such as cardiovascular and neural networks and intraorgan flow heterogeneities.

By the end of this whirlwind tour, the reader may be left wondering, Are concepts of fractals no more than a way of quantifying complex data sets, be they spatial or temporal? Or could fractal concepts actually deepen our understanding of the physiological system itself? One cannot help but wonder if, perhaps, scale-free "fractal" features evolved in physiological structures be-

cause they confer some evolutionary advantage. Physiology is sometimes taught using metaphors akin to those of a Rube Goldberg machine: A changes B which changes C and so forth. Such a deterministic device is susceptible to errors at any stage. If building in redundancy by evolving scale-free structures can reduce the susceptibility to errors, could this account for the apparent ubiquity of scale-free phenomena in physiology?

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An Interpretive Introduction to Quantum Field Theory

Paul Teller
Princeton U. P., Princeton, N.J.,
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Physicists tend to view the philosophy of science with (healthy?) skepticism, if not outright disdain, and they regard the physics-philosophy connection as a bridge over which new ideas flow in one direction only (guess which), with little useful return. In earlier times, Niels Bohr and Werner Heisenberg eagerly acknowledged the influence of metaphysical learning on their theories, but few of us today think about our subject philosophically. Even in the resurgent discussions on the foundations of quantum mechanics, physicists have apparently found professional philosophy of limited help.

Although *An Interpretive Introduc-*