flights, however; they have, perhaps wisely, preferred to consider achievable goals. Several important new techniques are described and discussed, with a strong emphasis on molecular studies, but with awareness of other approaches. Soil animals are recognized as potential controlling agents in several key processes. A word that regularly appears is holism. Several contributors use it as a defence of the functional groups approach. The implication is that dealing with the soil biota at the taxon level is reductionist. This seems to me to be a caricature: if we are to have any hope of understanding the role of diversity in determining and controlling ecological processes, we shall certainly need to be reductionist in that sense, but the purpose of working at the taxon level will be to gain a better understanding of the processes themselves: that is true holism.

Overall, however, one becomes strongly aware of the different ways in which belowground and aboveground ecology have diverged. There is strong emphasis on methodology and description, but in soil biology generally, there seems to be a lack of an ecological conceptual framework binding all this together. Issues that are of great interest to ecologists on a wider canvas, especially the properties of communities such as resilience, stability and persistence, are not apparently being tackled by the ecological community below ground. Is this because soil ecology has not yet advanced to a stage where such questions are meaningful, or because soil ecologists have become distracted by the complexity of the system and the methodological difficulties it poses and have failed to ask those questions?

Of course, our ability to answer (or even ask) any of these questions will depend on there being a supply of qualified and enthusiastic scientists. To some extent that is in the lap of governments, but it also depends on teachers who can inspire students to take an interest in the soil. A difficulty in that endeavour can be finding appropriate texts for courses in soil ecology. Ken Killham's student text is a useful addition that will appeal to many students, for its easy style and sensible construction. Soil zoologists may feel a little under-represented and the publishers could have made more effort with the general appearance, which is very traditional, but the book does fill a real gap in the market. Maybe its availability will persuade a few more of us to emphasize soil in ecology courses and ecology in soils courses, and so ensure that there will be enough soil ecologists to tackle the challenges that *Beyond the Biomass* starts to address.

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References

1 Groombridge, B., ed. (1992) *Global Biodiversity: Status of the Earth's Living Resources*, Chapman & Hall
2 Hawksworth, D.L. (1991) *Mycol. Res.* 95, 641–655

One thousand words = one millipicture

Fractals in Biology and Medicine

edited by T.F. Nonnenmacher, G.A. Losa and E.R. Weibel

Birkhäuser, 1994.
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ISBN 3 7643 2989 0

Humans are exceptional at identifying visual patterns in nature. Machines are not. This is largely because certain visual characteristics of natural objects, such as texture, fragmentation and complexity of shape, though easily perceived, are difficult to quantify using the traditional euclidean scheme. Why is this so?

Consider the fact that the basic building block of euclidean geometry is a simple, straight, line segment; for example, in calculus a curve is approximated by a polygonal arc with infinitesimal sides. Here complex shape must be achieved with a complicated function. A polynomial description of a fern leaf, for example, might involve thousands of fitted parameters. One must basically push a simple building block (the straight line) into a complex shape with a complicated function. Thus, quantifying complex and irregular shapes can be difficult in the euclidean scheme: because the building block is so uniquely simple, the function must be very complicated.

As we are beginning to learn, quantification of natural patterns can often be simpler with fractal geometry. Fractals are characterized by irregular shapes and outlines, ideally possessing geometric self-similarity as in a snowflake. In contrast to euclidean geometry, the complexity in fractal geometry comes largely from the basic building blocks; however, the process which generates the larger patterns is relatively simple. This simple process, recursion, involves echoing a simple rule over and over again, to produce a self similar geometry. Thus, fractal and euclidean geometry are conjugate approaches to the geometry of natural forms[1]. Fractal geometry builds complex objects by applying simple processes to complicated building blocks; euclidean geometry uses simpler building blocks but frequently requires complex processes.

Why are fractals so ubiquitous in nature? Since the publication of Mandelbrot's seminal book[2] in 1977, there has been a remarkable proliferation of examples of fractal geometry in nature. More than a fad, fractals may indeed be a natural way of describing many such patterns. Insofar as parsimony is more than a 13th century religious doctrine, it may be that the economical way in which fractals are generated mathematically reflects to some degree how nature produces many of the complex shapes we see. Thus, recursion, or the simple repetition of a rule over and over again at different scales, may be a common tactic in nature.

A number of fine examples of this are given in the recent symposium volume *Fractals in Biology and Medicine*. The appearance of this volume, which grew out of a conference held in Switzerland last year, is a timely testament to the growing recognition that fractals are receiving in the life sciences. This conference brought together, for the first time, specialists in many fields of biology and medicine to discuss their research on fractal geometry. Throughout the volume, one is struck by the diversity of applications and the potential power which these relatively simple techniques have to offer in the life sciences, and in particular in medicine and developmental biology.

In one example from the book, Weibel describes the pattern of bronchial division in the human lung. For the first 14 generations of bifurcation the reduction of diameter can be described by a constant scaling factor, $2^{(-1/3)}$. Interestingly, this ratio is well known to hydrodynamicists as the optimum diameter reduction if the total work of flow in a branched system is to be minimized. Thus the repeated application of the evolutionary optimal design solution is an example of self similar or fractal scaling. Here, the complex structure of lung tissue can be rendered by repeated applications of a simple rule; at each bifurcation, reduce the diameter by $2^{(-1/3)}$.

In a more abstract but nonetheless fascinating example from the book, self similar structure was reported by Peng *et al.* using the range growth method (e.g. Ref. 3) in intron-containing DNA or so called 'junk DNA' isolated from rat embryonic skeletal myosin. They basically found what amounts to self similarity in the long range correlations of purines and pyrimidines for these molecules. Thus, there is a better than 50:50 chance of a single purine being followed by another purine, and for a small purine-dominated clump to be followed by another small purine-dominated clump, and the same for larger and larger aggregate regions of the molecule. All of which is curious for a molecule whose evolutionary and functional significance is presently being debated.

Academic interest aside, a relatively large portion of the book contains papers showing how fractals can have considerable practical potential in medical diagnosis and screening for pathologies. For example, affiliates of Ary Goldberger's lab at Harvard Medical School (Peng *et al.*) showed intriguing evidence that the fractal properties of normal heart rhythms can be consistent with healthy feedback (anticorrelation; cf. Ref. 3), whereas diseased patients can have heart rate characteristics lacking such properties. As concerns tissue screening, Benhamou *et al.* presented initial evidence that showed how a fractal analysis could be used to screen for osteoporosis in trabecular bone from X-ray views of the microarchitecture. This is a case where the texture of the fine structure, though perceivable by the human eye, cannot be measured easily with euclidean methods. However, with fractal methods, the screening may be done by machine.

Because this was a symposium volume of over 30 primary research papers, the organization of papers was unavoidably loose. However, it contains a wealth of interesting examples, and in our view highlights the cutting edge of this field in medicine and developmental biology.

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References

1 Hastings, H. and Sugihara, G. (1993) *Fractals: a User's Guide For The Natural Sciences*, Oxford University Press
2 Mandelbrot, B. (1977) *Fractals: Form, Chance and Dimension*, Freeman Press
3 Sugihara, G. and May, R.M. (1990) *Trends Ecol. Evol.* 5, 79–86

Social organization

Nourishment and Evolution in Insect Societies

edited by J.H. Hunt and C.A. Nalepa

Westview Press,
Studies in Insect Biology, 1994.
£59.50 hbk (xii + 449 pages)
ISBN 0 8133 8439 7

The authors of the 13 chapters in this book were all charged with the same task, to review the role of nourishment in social evolution. The result was a great diversity of approaches. This diversity reflects the absence of consensus, among people that study social insects, about what social organization is. Social insect colonies or associations tend to include one or more individuals that reproduce, and some that do not. But there is more to social organization than who lays the eggs. The egg-layer, or 'queen', does not direct the behavior of her nestmates. Instead, colonies function without any central control. Social organization produces coordinated activities, such as nest building and group foraging, and leads to allocation of effort among various tasks to track the colony's environment. The gathering and distribution of nutrients is a crucial function of social organization.

Social evolution means different things in different chapters of this book. Several authors consider, from an ecological perspective, the question of which individuals in a colony reproduce, and whether reproductives help feed their offspring. How does food limitation influence the necessity for parental care? Others apply existing theory on the evolution of parental investment to social arthropods. These chapters could be used to bring social insects into general behavioral ecology courses.

Several chapters discuss the role of food in the organization of large colonies of eusocial species. Some consider how nourishment influences the differentiation of morphologically distinct reproductives and workers. Others consider whether nutrition leads to differences among workers in the tasks they perform. Wheeler's chapter documents the strong suspicion, shared by many, that nourishment affects an individual worker's transition from one task to another, or that nourishment helps determine worker size in those ant species where adult size is correlated with task specialization. As yet, however, there are no data showing how nourishment influences which task a worker performs, though studies of colony ontogeny in fire ants offer some intriguing suggestions[1,2]. How individuals are allocated to various tasks depends on colony size[3], and here Lenz considers the relation of food source and mature colony size in termites.

For some authors, social evolution means the evolution of colonial living from looser associations. These authors take a comparative approach to the relation of nutrition and social behavior. The type of food resource, or the way food is transferred among individuals, is used as a taxonomic character. The problem is to explain how feeding ecology and behavior may be related to the extent of sociality. But the degree of social evolution of a given species is difficult to establish. The stages leading to eusociality have been defined in several ways, sometimes inconsistent across taxa of social insects; Kukuk[4] recently suggested some better definitions. Because of the variety of existing definitions, many phylogenetic routes have been suggested for the evolution of sociality. Arguments based on nutrition suggest further possibilities. Darlington's chapter on the digestive physiology of fungus-growing termites stood out for me as a remarkably clear and interesting piece of writing that managed to avoid any of the pitfalls of general definitions of sociality.

The contributors to this book worked hard to bring together a diffuse literature and point out where future work is needed. The book will inspire new research on the role of nutrition in shaping the organization of social insect colonies.

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References

1 Tschinkel, W.P. (1993) *Ecol. Monogr.* 63, 425–457
2 Howard, D.F. and Tschinkel, W.P. (1981) *Phys. Entomol.* 6, 297–306
3 Gordon, D.M. (1989) in *Oxford Surveys in Evolutionary Biology* (Vol. 6) (Harvey, P. and Partridge, L., eds), pp. 52–76, Oxford University Press
4 Kukuk, P.F. (1994) *Anim. Behav.* 47, 1475–1478

Long-term population biology

Quantitative Ecology and the Brown Trout

by J.M. Elliott

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£35.00 hbk, £14.95 pbk (xi + 286 pages)
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There is increasing recognition of the need for realistic mathematical models of population dynamics and growth. One major aim of *Quantitative Ecology and the Brown Trout* is to illustrate the value of such models, as tools for understanding ecological processes and for conserving and managing populations. This aim is addressed mainly by a detailed review of the author's own study (lasting more than 25 years) of the dynamics of an anadromous brown trout population in Black Brows Beck, in the English Lake District. In the process, another major aim of the book is realized, since this work and the conclusions derived from it demonstrate very clearly the value to ecological research of long-term studies of specific populations. Elliott discusses this issue succinctly, but with justifiable passion, identifying the main objectives of such studies as providing reliable estimates of baseline variation, detecting long-term trends, detecting rare events and providing a valuable database for testing ecological hypotheses and quantitative models. In his own words, 'A blunt version is that long-term investigations may prevent ecologists drawing foolish conclusions from short-term studies'. As he points out, 'It is debatable whether the long-term study ... could have started in the