# Preface. Towards the marriage of theory and data

Simon A. Levin

*Interface Focus* published online 1 February 2012
doi: 10.1098/rsfs.2012.0006

## References

This article cites 12 articles, 2 of which can be accessed free
http://rsfs.royalsocietypublishing.org/content/early/2012/01/31/rsfs.2012.0006.full.html
#ref-list-1

**P<P**

Published online 1 February 2012 in advance of the print journal.

## Subject collections

Articles on similar topics can be found in the following collections

- biocomplexity (15 articles)

## Email alerting service

Receive free email alerts when new articles cite this article - sign up in the box at the top right-hand corner of the article or click [here](http://rsfs.royalsocietypublishing.org/content/early/2012/01/31/rsfs.2012.0006.full.html)
INTRODUCTION

Preface. Towards the marriage of theory and data

Theoretical biology is a subject with a rich history, tracing back certainly to demographers such as Graunt [1], and also drawing inspiration from perhaps the most important biological theoretician of all, Darwin [2]. Although Darwin did not deal in mathematics, his use of deductive reasoning to provide a conceptual framework for an otherwise confusing body of observations, and to make testable predictions, is the model for what theoretical biology should be.

Quantitative approaches to biological problems have been around for a while, among demographers such as Graunt, as well as among others such as Verhulst [3] and Quetelet [4,5], who addressed Malthus’s [6] challenges of population regulation. However, in the first part of the twentieth century, the subject was elevated to a new level: in ecological systems by the sophisticated mathematical contributions of Volterra [7] and Lotka [8]; in population genetics by Wright [9–11], Fisher [12,13] and Haldane [14,15]; and in epidemiology by Ross [16] and by Kermack & McKendrick [17].

No course in ecology is complete without a discussion of the equations of Volterra and Lotka, describing the dynamics of interacting species; despite their reliance on mathematical techniques that may be unfamiliar to some ecologists, their essential elements can be translated into terms that all can understand, and led early on to close links to experimental work, such as the studies of Gause [18], Park [19] and Utida [20].

The legacy of Volterra and Lotka has not been universally positive, although this is certainly not their fault. The attractive simplicity of the model equations proved irresistible to mathematicians eager to add bells and whistles, with little concern for biological relevance, and to explore their tortured implications in painful detail. This has produced a large literature, harmless except for its effect on perceptions of the field of mathematical biology, and its obfuscation of the cryptic nuggets that sometimes lie within.

I was influenced early in my career by the distinguished probabilist Mark Kac [21], who wrote that the great contributions of physicists to biology had been carried out by physicists who had become biologists; that perceptive insight would be even more valid today. In interdisciplinary work, the standards for success must rest in whether the problem of interest has been solved, or at least illuminated, not in the elegance of the methods. This Theme Issue and the meeting from which it arose are dedicated to that principle, and in particular to the importance of confronting theory with data.

When I first entered theoretical biology in the 1960s and 1970s, the most exciting things for me to read were wide-spectrum volumes, such as Waddington’s [22–25] Towards a Theoretical Biology, which brought together broad thinkers from biology and other disciplines to look for commonalities across systems in such phenomena as pattern formation, periodicities and bifurcations. Abstract mathematical work, such as Rene Thom’s theory of catastrophes, attracted wide interest for a while because of the perceived potential, unrealized, to provide a unifying framework for similar phenomena in diverse applications. Theoretical biologists eagerly swarmed to meetings such as the Gordon Conferences in Theoretical Biology and Biomathematics to share insights, and commiserate with one another about how unappreciated they were among biologists. Lecture notes volumes appeared that individually had little focus because of their wide scope, but nonetheless were scooped up and read avidly by mathematicians and physicists seeking points of entry into biology.

More focused monographs began to attract attention also from mathematically inclined biologists seeking new insights into their own fields, as well as from mathematicians and physical scientists interested in digging deeper into the biological details. The situation has changed dramatically in the decades since. I rarely see many of the colleagues I used to see regularly, because I attend more specialized meetings in ecology and evolutionary biology, whereas they attend meetings in their particular areas of application. This is a good thing, because it means we have all taken Kac’s recommendations to heart—explicitly or implicitly—by becoming biologists and taking possession of the problems on which we work. My graduate students and postdoctoral fellows find jobs in ecology and evolutionary biology departments rather than mathematics departments, and this changes the standards by which they judge their own work: instead of valuing mathematical elegance above all, they rather place the greatest emphasis on what they have contributed to the solution or at least understanding of...
a problem. Theories for them no longer float in the abstract, but are confronted with data. That is the rationale for the excellent collection of papers that appear in this Theme Issue, and I think is emblematic of the maturation of a discipline. All of the papers in this issue illustrate the continuing challenges of understanding collective phenomena, from bacteria and amoebae to fish and birds to collective decision-making in human societies. My prediction is that the next decade will include an expansion of interest in these issues, on the more general problem of the organization and robustness of complex adaptive systems from individuals to the biosphere and the interlinked global socio-economic system. In all such systems, macroscopic patterns emerge from the interactions among large numbers of individual agents, and the challenge is to develop a statistical mechanics for such systems, connecting the microscopic and the macroscopic.

Collective decision-making, in which individuals share information intentionally or accidentally, is one of the most exciting areas of research in behavioural ecology and behavioural economics, uniting the two disciplines in a rich framework with implications for our potential to solve humanity’s problems. We live in global commons in which no individual is an island, and in which the decisions one makes can affect everyone. Preserving our common resources for all to enjoy—now and in future generations—of course not only raises issues of ethics but also raises very practical issues about how agreements can be reached and sustained. Cooperation is a well-studied, albeit not completely understood, phenomenon in biology; and indeed, extreme forms of cooperation, such as eusociality, so puzzled Darwin that it delayed publication of On the Origin of Species until 1868. Today,TagName=an essay on the principle of population. London, UK: J. Johnson.


Introduction. Marriage of theory and data  

S. A. Levin


