Economics is unique among the social sciences in many ways. It seems naturally the most mathematical, its data are among the most easily quantified and profuse, and it has had the most extensive exchange with the natural sciences of any social study. The question whether there are universal methods of scientific inquiry that apply equally to nature and society was foremost in the minds of the inventors who laid many of the foundations for modern quantitative economic theory in the late 1800s. Recently, after a century in which mainstream economics and the natural sciences have grown progressively apart, there has been a decade of intensive effort within a few communities to reintegrate natural-science thinking into economics. Part of this has come from an exchange with nonlinear and statistical physics now known as “econophysics,” part has come from integration of evolutionary concepts from biology, and part has come from an attempt to make contact with empirical cognitive sciences. Not all of this work is new within the decade; much of it has resulted from the crystallization of communities of researchers around ideas that were first proposed by individuals a half-century or more ago.

The past decade of work, combined with changes that have been brewing from internal sources within economics itself, have led to a time for reassessment. What have attempts at integration accomplished, and what important work remains to be done? Have the original cross-overs with physics or biology fulfilled the conceptual or quantitative needs they were intended to address? Have changes in economic thinking, or in the complexity of economic life, created new opportunities that were not foreseen but should be pursued now? Finally, has any of this work fundamentally changed what we think economics is, or demonstrated that a natural unity is possible in thinking about social and natural phenomena?

The five papers in this volume consider various aspects of modern economic practice and theory, in connection with ideas that have arisen in the study of complex systems. Among the natural sciences, ideas originating in physics, and to a lesser extent in computation theory, are most prominent. Similarly, many of the articles in quantitative finance are written from this perspective, where high-frequency data on market function have proved particularly amenable to the exploration and validation of new ideas. However, opportunities both within economics, and in cross-fertilization with several natural sciences, extend well beyond these conceptual domains, and the papers mention a few of these.
The mainstream economic theory of today, known as neoclassical or marginalist economics, is built around a quasi-mathematical concept of equilibrium, which is then used to motivate various concepts of rationality and even some implicit assumptions about how markets clear. Farmer and Geanakoplos review the merits and limitations of equilibrium as a foundation for economic thought, providing a modern perspective on many of the questions that first drove the emergence of econophysics. From both the successes of the last decade, and important outstanding problems in finance and market stabilization, they suggest frameworks for thinking about economic dynamics that could possess comparable richness to the accepted framework for equilibrium.

The paper by Lillo provides a critique of econophysics from "within" the paradigms of the discipline, as it has matured and taken an identity of its own within the last decade. He considers particularly the question of whether markets function efficiently, as they are asserted to do within neoclassical economic theory. This assertion has been severely challenged, and the question underlying it given new life, by work in econophysics. Two very different questions are whether markets satisfy empirical criteria of efficiency, and whether they fulfill traditional economic conditions put forth as explanations for doing so.

Often, the classical conditions are rather strongly violated, yet operationally markets remain much more efficient than would be expected as a result. The ability to use structure and regularities in data to make sense of such observations provides one illustration of how natural and social science questions and methods can be merged.

The particular approaches associated with econophysics have grown up together with the treatment of non-Gaussian, or heavy-tailed distributions in prices series, income and wealth distributions, and other social phenomena. These "excesses" of rare events have pointed, perhaps more than any other quantity, to inadequacies of equilibrium theories, and have provided much of the support for ideas drawn from natural sciences to study them. An ongoing debate in both econophysics and economics more generally is whether these tails should be understood and modeled as power laws. Mandelbrot, who offered both data and argument challenging both the conventional wisdom and the evidence underlying stochastic process models in finance more than 50 years ago, reviews the case and consequences for power-law interpretation. He focuses on the grounds for prior preference among classes of distributions, which has been a long-standing component of theory in the natural sciences, but is often avoided in economics in favor of non-parametric estimation or similar bias-avoidance schemes.

Surely, the most complex ramifications of heavy-tailed distributions are found in quantitative finance, both in terms of analysis and in terms of the real growth in the complexity of economic life. Not only are the moments of return distributions themselves a basis for pricing: they are the foundation for portfolio allocation and for tiers of derivative instruments used in both hedging and speculation. When heavy tails have been considered, that has often been done within the context of asymptotically stable solutions of the central limit theorem, where power laws are linked to the difference between finite and infinite variance. The paper by Taleb adopts the viewpoint of the scientifically trained practitioner, identifying four main problems that result from the use of common finance models for heavy-tailed return distributions. He considers the errors that result from excluding finite-variance power-law distributions, correlated observations away from the asymptotically stable regime, and the convergence of nonasymptotic with asymptotic features of distributions.

The papers by Farmer and Geanakoplos, and by Lillo, address the adequacy of concepts of equilibrium and efficiency, whereas those by Mandelbrot and by Taleb address the role of theory in the assignment of simple functional forms to probability distributions, and the consequences of such assignment. The last paper, by Shubik and Smith, has overlaps with these, but primarily questions the foundation of economics as a science of quantities at all. They consider the problems of taxonomy, pre-measurement and measurement of economic and financial observables, stressing the role of finance (and to some extent physical capital) as a catalyst and a controller. The associations in this paper are perhaps less with physics and mathematics than with computer science and even chemistry, where the problems of constructing and controlling complex, contingent sequences of unfolding events have been studied.

The perspective from these reviews is that much progress has been made, especially in data-rich applications in domains such as finance. These are not merely gains in method; natural-science modes of data interpretation and model validation are impacting core concepts about market function. At the same time, many questions of fundamental interest to economists are not reflected in this work, and whether they fit within the methodology of natural as well as social science remains an open question. At least, for the present, the answer is not clearly "no."