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Chaos and Coarse Graining in Statistical Mechanics by Patrizia Castiglione, Massimo Falcione, Annick Lesne and Angelo Vulpiane, Cambridge University Press, 2008, pp. x + 268. Scope: monograph. Level: professional physicists, researchers and PhD students.

A deep chasm still separates the microscopic world of atoms and molecules from the familiar macroscopic world that is part of everyday life. These worlds are profoundly different. In the former, time is reversible and the dynamics is Hamiltonian whereas, in the latter, we see dissipation, increasing entropy, and a very definite arrow of time. For equilibrium systems, Boltzmann's revolutionary ideas of a century ago provide deep insight, and have stood the test of time. Supplemented by the quantum statistical mechanics that came later, they lead to an excellent description of large-scale behaviour based on properties at the atomic and molecular scale. Thus equilibrium thermodynamics can be derived convincingly from statistical mechanics, with only a few leaps of faith along the way. The only requirement is that the number of particles should be large. For non-equilibrium and open systems, however, there are few such certainties. The discovery (or rediscovery) of dynamical chaos added a further dimension to the problem, because the statistical features typically observed in systems with many degrees of freedom can also be generated by deterministic chaos in simple systems. So what is the connection, if any?

The main aim of the authors is to show that a proper understanding of statistical mechanics requires a combination of concepts and techniques developed for dynamical systems, as well as the usual statistical ideas. The book consists of 8 chapters, falling into 3 fairly distinct parts. Their intention was not to write a treatise on either dynamical systems, or on statistical mechanics, but to try to bring these two topics together in a fairly self-contained and coherent kind of way.

The first three chapters provide an introduction to deterministic chaos and complexity. They cover topics like unpredictability, chaos, probabilistic treatments, Lyapunov exponents, entropies, information theory, and coarse-graining. In Part II the authors change gear abruptly, embark on the fundamentals of statistical mechanics, and discuss ergodic theory. But fairly quickly, dynamical ideas also creep in, including the connection between non-integrability and ergodicity, the KAM theorem, and the role of chaos in statistical mechanics. There are interesting historical remarks about the contributions of Fermi and Kolmogorov. Chapters 5 and 6 take the bull by the horns and tackle the origins of macroscopic irreversibility, and the role of chaos in non-equilibrium statistical mechanics respectively. Coarse-graining returns at the start of Part III, in Chapter 7, where the authors describe four distinct levels of description: microsccopic, describing solvent and colloidal particles (in terms of the Hamiltonian equations of motion and the Liouville equation); mesoscopic I, describing only colloidal particles (stochastic equations, Kramers equation); mesoscopic II, describing only the positions of colloidal particles (stochastic equations and Smoluchowski equation); and finally the macroscopic level, describing only spatial distributions of colloidal particles (Fick equation). The closing chapter is devoted to the renormalisation group (RG) as a means of deriving "effective low-dimensional descriptions to capture large-scale and/or long-term behaviour". Although the account is succinct, it covers RG philosophy, relationship to multiscale approaches, scaling theories, critical exponents, Green's function approaches, central limit theorem, and much else.

Have the authors succeeded in pulling together this broad sweep of physics into a single entity? I believe that to a large extent they have. The book is mostly written in very good English, albeit rather Italianate: native speakers may find it hard to skim-read because sentences sometimes have to be re-read, in order to find where to place the emphasis. But this hardly matters, as it is a high level text that requires close attention anyway and there will be relatively few physicists who are familiar with all the diverse areas covered. It can be recommended for senior postgraduate students and researchers interested in a fresh perspective on the links between microscopic and macroscopic physics. They will find many useful ideas and connections and, although there are no easy answers, that a broad picture does seem to be emerging.

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