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Book Review

Physics of Self-Organization and Evolution
Wiley-VCH, Weinheim, 2011, ISBN 978-3-527-40963-1
By Rainer Feistel and Werner Ebeling

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Thirty years ago, in 1982, the well-known German language book *Physik der Selbstorganisation und Evolution* was published by Werner Ebeling and Rainer Feistel (Akademie-Verlag, Berlin, 1982). Now, an updated version, completely re-written and adapted to account for the vivid development in the fields of self-organization and dynamical systems, also including 47 pages of references of recent literature, has been re-elaborated by the authors. As in the former German book, this new edition is also devoted to bridging the concepts of irreversible thermodynamics and nonlinear dynamical systems to self-reproduction, selection, evolution processes, and self-organization. The authors dedicate this revised edition to "former students, coworkers, and friends who helped to work out our ideas". But besides them, the book can be highly recommended for all who are interested in the experimental and theoretical fundamentals of self-organizing systems. The authors take examples from physics, chemistry, biology, and social systems, including results which are yet unpublished in English.

The book consists of 10 chapters:

• Introduction to the Field of Self-Organization • Fundamental Laws of Equilibrium and Non-Equilibrium Thermodynamics • Evolution of the Earth and the Terrestrial Climate • Nonlinear Dynamics, Instabilities and Fluctuations • Self-Reproduction, Multistability and Information Transfer as Basic Mechanisms of Evolution • Competition and Selection Processes • Models of Evolution Processes • Self-Organization of Information and Symbols • On the Origin of Life • Conclusion and Outlook

In the more familiarly written "Preface", the authors give a short historical overview of the development of self-organization since Prigogine's great lecture on that topic delivered in Moscow in 1970. As a striking example for an unpredictable stochastic event, the fall of the Berlin Wall

is mentioned, taking it for intensifying the motivation to investigate self-organization.

In the "Introduction", a short history of cosmic evolution is given and fundamental concepts such as entropy, equilibrium, non-equilibrium, laws of thermodynamics, dynamics, stability and instability are briefly discussed. Self-organization is defined as a "process in which individual subunits achieve, through their cooperative interactions, states characterized by new, emergent properties transcending the properties of their constitutive parts".

Chapter 2, "Thermodynamics", elucidates the items mentioned in the introduction: basic variables, equation of state, quasistatic, reversible and irreversible processes, entropy, and Gibbs fundamental relation. Unfortunately, this chapter is mostly formulated according to the old-fashioned version of thermodynamics of the 1950s, except that part on irreversible radiation transfer which fits into today's thermodynamics. Non-equilibrium and internal variables are missing in the state space, resulting in a restricted Gibbs fundamental relation. The thermodynamic condition of self-organization and the Glansdorff–Prigogine evolution criterion are correctly mentioned, whereas the questionable theorem of Prigogine is not discussed in detail. These shortcomings have no influence on the following chapters and can be corrected easily in a future edition of the book.

In Chapter 3, "Evolution of the Earth and the Terrestrial Climate", which is virtually a monograph (76 pages), the photon mill, the black-body radiation model of the Earth, and the greenhouse effect are discussed, among other things. A funny photo of one of the authors (R.F.) in the Atlantic and a long list of events in the early history of the Earth can be found in this chapter, together with numerous figures on pressure, temperature, global cells, dynamical sea currents, an iceberg, and a wind hose. In the black-body radiation model, the non-equilibrium contact temperatures for the radiation exchanges between Sun and Earth, and Earth and cosmos are derived together with the entropy production of the Earth–Sun system. As demonstrated, its steady state is only in linear approximation consistent with Prigogine's theorem, while the nonlinear steady state does not coincide with an extremum of entropy production.

The basic concepts and tools needed in the following parts of the book are gathered in Chapter 4, "Nonlinear Dynamics, Instabilities, and Fluctuations". Binary relations, Hamiltonian systems and their flux in the state space, the Lyapunov exponent with regard to limit cycles and attractors, remarks on predictability and the Smoluchowski–Fokker–Planck equation are briefly presented, accompanied by numerous citations which allow

more detailed study. Graphs, stochastic processes on networks and, last but not least, the master equation, essential for the subsequent chapters, are considered.

In Chapter 5, "Self-Reproduction, Multistability, and Information Transfer as Basic Mechanisms of Evolution", kinetic equations of chemical reactions are considered for discussing the items mentioned in the title of the chapter. Starting with the master equation, the survival of a newly appearing component is investigated by stochastic analysis in bi- and multistable systems. An overview of the concept of information value according to Stratonovich and Volkenstein concludes the chapter by considering two elucidating examples.

At the beginning of Chapter 6, "Competition and Selection Processes", basic concepts in connection with the system of nonlinear ordinary differential equations of first order are discussed in detail with respect to historical and significant facts. For the classification of selection processes, a hierarchy of extremum principles is presented in a diagram. Most of the chapter is devoted to models of competition using dynamical, stochastic, and graphical methods. Subchapters on hyperselection, selections in ecological and social systems characterize the main chapter (73 pages) of the book.

Chapter 7, "Models of Evolution Processes" (50 pages), which is devoted to the search of various evolution processes, is also a main chapter. Starting with the Fisher–Eigene equation, the evolution of smooth, random, and Lotka–Volterra fitness landscapes is investigated. The final part of this chapter deals with Boolean reaction systems using set-theoretical methods.

Chapter 8, "Self-Organization of Information and Symbols", begins with an introduction to symbolic information and Shannon's information concept, without considering the formal axioms of information. The emergence of symbolic information and its general properties are discussed from the perspective of a kinetic phase transition. In contrast to Chapters 6 and 7, this chapter is less formal and more descriptive, discussing items such as structural information, genetic code, morphogenesis, neuronal networks, and more. This chapter, together with numerous references, represents a concise introduction to different fields, each of which requires a more detailed treatment beyond the scope of this book.

In Chapter 9, "On the Origin of Life", the authors emphasize that the issue of the origin of life is among the most difficult questions of modern science. From the appearance of the first cells, a more than thousand-million-year non-equilibrium random process, proceeding in catalytic cascades, may describe the development of life which originates in the

existence of replicated chain molecules processing symbolic information. Thus, the DNA–RNA cycle is discussed, and the chapter ends with considerations on Darwinian evolution.

Chapter 10, "Conclusion and Outlook", is devoted to a summary of some basic views which are developed in this book. Although only 10 pages in length and at the end of the book, this chapter is one of the most essential ones apart from those which provide the formal background: One aim of the book is to describe the search for universal extremum principles forming the basis of understanding the evolutionary processes which influence our world. Beyond the usual concepts of physics, "emergent properties" representing holistic, irreducible properties of the considered system – consistent with the fundamental laws of physics – and "values" determining its evolution are needed. Special variables – slaved ones, control and order parameters – have to be found for formulating adequate evolution equations which may be not local in time, showing "historicity".

Interesting are the final remarks on the future of evolution: Because any prediction on the future of evolving systems is inevitably associated with large unavoidable uncertainties (as demonstrated in Chapter 4), the future of global warming cannot predicted, especially since the role of atmospheric vapor and clouds and also that of photosynthesis cannot be properly taken into account. Therefore, one needs more adaptive and flexible strategies in the study of Earth's atmosphere, sea research, and also in forestry.

The book is not only valuable for "former friends", but can be warmly recommended for all who are interested in self-organization and evolution. Although the book is not written as a textbook, Chapters 4 to 7 in connection with the huge number of references make a study of this field possible for beginners, too. Also experts in this field can find new aspects in this extensive, detailed, and clearly written survey of a large variety of evolution processes.

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