Preface

The first volume of reviews *Order, Disorder and Criticality* was published by World Scientific in 2004 and, over time, it gave rise to the book series with the same title.[1] This series continues with this, the sixth, volume. The reviews in the series originate from the *Ising Lectures*[2] - workshops that occur annually in Lviv (Ukraine) and serve as meeting points between renowned scholars and students. The reviews herein follow the style of presentations in the Ising Lectures: they introduce new and emerging fields of research to a wide audience making state-of-the-art studies accessible to a wide range of readers.

The series initially aimed to provide pedagogical introductory reviews of topics related to phase transitions and criticality under discussion in contemporary physics literature. Gradually, it broadened to include a wider class of systems – namely those beyond physics for which the concepts of phase transitions, criticality and methods of statistical physics are applicable. These complex systems are composed of many interacting components which display collective behavior that do not follow trivially from the behaviors of their individual parts. Therefore, this series now addresses both the critical behavior of traditional physics systems and other complex systems. Statistical physics offers common methodological and conceptual frameworks that enable consideration of such systems from a unified point of view.[3]

The chapters of this volume reflect this dynamically evolving remit. Thermal and quantum phase transitions are considered in the first two chapters: *Nature of the spin glass phase in finite dimensional (Ising) spin glasses* by Juan J. Ruiz-Lorenzo and *Phase transitions in Fermi systems*

[1] *Order, Disorder and Criticality. Advanced Problems of Phase Transition Theory*, edited by Yu. Holovatch (World Scientific, Singapore), vol. 1 – 2004, vol. 2 – 2007, vol. 3 – 2012, vol. 4 – 2015, vol. 5 – 2018.
[2] See: http://www.icmp.lviv.ua/ising/
[3] Yu. Holovatch, R. Kenna, S. Thurner. *Complex systems: physics beyond physics.* Eur. Journ. Phys. **38** (2017) 023002.

by Paweł Jakubczyk. The spin glass phase is caused by an interplay of structural disorder and frustrations and is classical in its origin. Fermi systems, on the other hand, are by definition quantum and are influenced by both classical and quantum effects. Introducing the reader to variety of phenomena occurring in these systems, the first two chapters also present powerful methods used in their analysis, including computer simulations and renormalization group theory. Since spin glasses typify complex systems, the notion of complexity appears already at the beginning of the book and is further elucidated in subsequent chapters. Through this layout, the reader becomes acquainted with common features of the behaviours of complex systems of different nature: sensitivity to minor changes in external parameters, emergence of new properties, self-organization, and fat-tail (power-law) distributions.

The next two chapters, *Geometrical frustration in interacting self-avoiding walk models of polymers in dilute solution* by Damien P. Foster and *Two-dimensional systems of elongated particles: From diluted to dense* by Nikolai I. Lebovka and Yuri Yu. Tarasevich provide examples of criticality that can be tuned by changes in system geometry. Indeed, collective effects and scaling discussed in these chapters are due to changes in concentration as occurs at percolation and changes in chain length in the case of self-avoiding walks. In spite of differences in causalities of the emerging effects, properties of these systems in the vicinity of their corresponding critical ("tipping") points are strikingly similar to those that are manifest during thermodynamic or quantum phase transitions. In particular, their universality is revealed by the power laws that govern certain properties in the vicinity of the transition point. Furthermore, these two chapters provide examples of physical processes that serve as archetypes for collective phenomena occurring far beyond traditional physics and very often common in complex systems: percolation and diffusion. The first one is considered there in a more general settings of finite-size objects of different shapes that may lead to jamming phenomenon too. The second one, as a random walk problem, lies at the origin of numerous phenomena where statistics of interacting self-avoiding and random walks is important. An example provided here concerns thermodynamics of polymers in an infinite dilution limit.

The final two chapters discuss dynamical collective behaviour that arises in systems of many interacting agents, these are *Modeling tumor growth: a simple individual-based model and its analysis* by Yuri Kozitsky and Krzysztof Pilorz and *Microscopic and macroscopic models for vehicular*

and pedestrian flows by Massimiliano D. Rosini. Here, one considers proliferation in tumor cell growth as well as changes in car and pedestrian flows caused by variations in external parameters and in individual agent behaviours. These chapters present both agent-based modeling which is along with the approach of statistical physics based on consideration of individual particles as well as they exploit macroscopic models, resembling phenomenological approaches of hydrodynamics and thermodynamics.

To summarise, this volume presents problems in phase transitions and critical behaviour in various systems and shows how recent research attempts to solve them. Gathered together, the chapters of this book show how the conceptual framework and methods of statistical physics are used in understanding emerging behaviour of complex systems of many interacting agents and in a natural way become a part of a complex system science. I am truly grateful to the authors of this volume for their contributions and to World Scientific for their continued interest in this topic and encouragement in publishing this volume. Special thanks to Yulian Honchar, Ralph Kenna and to my colleagues from the Laboratory for statistical physics of complex systems, for their help in preparing the book.

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