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Stochastic Processes in Physics, Chemistry, and Biology

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Preface

The theory of stochastic processes originally grew out of efforts to describe Brownian motion quantitatively. Today it provides a huge arsenal of methods suitable for analyzing the influence of noise on a wide range of systems. The credit for acquiring all the deep insights and powerful methods is due mainly to a handful of physicists and mathematicians: Einstein, Smoluchowski, Langevin, Wiener, Stratonovich, etc. Hence it is no surprise that until recently the bulk of basic and applied stochastic research was devoted to purely mathematical and physical questions.

However, in the last decade we have witnessed an enormous growth of results achieved in other sciences – especially chemistry and biology – based on applying methods of stochastic processes. One reason for this stochastics boom may be that the realization that noise plays a constructive rather than the expected deteriorating role has spread to communities beyond physics.

Besides their aesthetic appeal these noise-induced, noise-supported or noise-enhanced effects sometimes offer an explanation for so far open problems (information transmission in the nervous system and information processing in the brain, processes at the cell level, enzymatic reactions, etc.). They may also pave the way to novel technological applications (noise-enhanced reaction rates, noise-induced transport and separation on the nanoscale, etc.). Key words to be mentioned in this context are stochastic resonance, Brownian motors or ratchets, and noise-supported phenomena in excitable systems.

A second important field where noise can play an eminent role are phenomena of structure formation. Spirals, fronts, kinks, interfaces, domains, growing surfaces, etc., usually modeled theoretically by physicists, are important for many real phenomena in physics, chemistry and biology, e.g. current filaments in semiconductors, catalytic reactions on surfaces, and the complex dynamics of the heart, of the brain, or of ecosystems.

It is an amusing fact of history that the theory of stochastic processes was initiated in 1828 by Robert Brown's observation of the irregular motion of pollen grains suspended in water. As a botanist – which is more akin to a biologist than to a physicist – he was inclined to explain his observation by endowing the pollen grains with a vital force, the molecules of life. Actually, his biologically inspired idea has been revived recently by physicists opening the research field of active Brownian particles. Later, Brown convinced himself – and others – that tiny particles of inorganic substances were also subjected to the same motion. As a consequence, Brownian motion soon drifted from biology to physics where Einstein (1905) and Smoluchowski (1906) published theories, which proved to be a first major breakthrough. From this perspective it is interesting to see that stochastic processes and Brownian motion have made their way from biology to physics to chemistry and back to biology.

The present book is a collection of short articles, which together reflect and describe the fields in which applied stochastics is currently most fruitful and promising. Many of the authors are renowned experts in today's hot topics and have strongly influenced their own research fields. The presentation is intended to be pedagogical and self-contained. To achieve this, each article went through a refereeing process. The book will thus be accessible to graduate students; but also scientists active in one of the fields – or contemplating entering a new field – should find much useful material reflecting the state of the art.

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DEDICATION

The authors and the editors dedicate this book to Lutz Schimansky-Geier, Professor for Stochastic Processes at the Humboldt University at Berlin, on the occasion of his 50th birthday.

Berlin,
June, 2000

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