# 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

*Jan Freund*
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# Foreword:
# Lutz Schimansky-Geier: The Earlier and the Later Years

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$\Sigma\tau o\chi\alpha\sigma\tau\iota\kappa o\sigma$ – its root, $\sigma\tau o\chi o\sigma$, means variously "arrow", "aim" or "objective", but already the ancient Greeks realized that hitting or missing the target was a chance process – dependent on the whim of the Gods - and hence it took on the implication of randomness. In the early days of radio, the random arrival of electrons at the anode of a vacuum tube caused a hissing sound in loud speakers which the engineers called "noise". Thus "Applied Stochastic Processes" are that class of phenomenon which involve noise as an essential ingredient, either to the inherent effectiveness of the process or to its fundamental understanding. To those early engineers – and indeed to many even today, having absorbed linear transform theory with their mother's milk – noise was (is) an unavoidable nuisance, greatly to be despised, always to be minimized and at all cost! But in spite of this mind-set a modern field involving basic studies of stochastic processes in diverse *nonlinear* systems has grown vigorous, attractive and influential.

Today the field of nonlinear stochastic processes is vigorous and productive. It combines the more traditional aspects of classical and quantum statistical mechanics with the newer field of deterministic, nonlinear dynamics. The latter field gave birth to chaos theory that has impacted virtually every area of scientific research from mechanics and engineering through astrophysics to biology and medicine. More recently, studies of high-dimensional stochastic processes in combination with low-dimensional, deterministic dynamics have become important. This is true especially in biology and medicine, where noise is ubiquitous, and where the detection of low-dimensional processes buried within the noise, for example, in the control of chaos, have become important. Thus today we observe vigorous and dynamic research activity in areas wherein Lutz Schimansky-Geier [LSG] made fundamental contributions already nearly 2 decades ago.

As with all fields, its robust health today owes everything to a few early pioneers: those who put forth clear theories gleaned from studies on paradigmatic systems. In our field, *the* paradigmatic system is the bistable potential – the so-called "standard quartic" – and LSG easily qualifies as an early pioneer with his book, *Noise and Diffusion in Bistable Nonequilibrium Systems*, published together with a colleague, H. Malchow, in 1986 by Teubner.

Today, our field is characterized by three descriptors: *nonlinear, nonequilibrium*[1] *and dynamical*, and one can discern all three as major influences in the aforementioned early book. So we began to study how bistable dynamical systems respond to noise first in the overdamped limit and later, alas with appropriate approximations, how underdamped, or inertial systems dynamically evolve. LSG was in the thick of this, with a series of papers commencing in the very early 1980's published initially with his mentor, Prof. Dr. Werner Ebeling. Especially notable were early studies on noisy biochemical oscillators as well as the effects of noise on the propagation of wave fronts in excitable media, topics which years later were destined to become "hot" in the general community of nonlinear scientists[2]. The late 80's saw Lutz continuing to make fundamental studies of spatio-temporal dynamics with noise, for example in the Belousov-Zhabotinski chemical reaction and at the same time opening up the door to studies of the so called "colored" noise in nonlinear systems. Soon after, he made seminal studies of "harmonic noise", or noise with a preferred frequency. Harmonic noise is useful even today in quite practical studies, sometimes for odd or unforeseen applications, for example, of the strange electrical signatures of certain zooplankton upon which even stranger fish feed by exclusive means of an electrical sense. The early-to-mid 90s saw Lutz turn his attention to stochastic resonance with a seminal series of papers wherein the phenomenon was exhibited and studied in a variety of unique and novel systems with current applications in both physics and biology. These studies included original applications of stochastic resonance to spatio-temporal systems. Today he is triggering new theories of stochastic resonance using modern information theoretic techniques, studies that will soon be applied in sensory biology. "Applied" is a key adjective. LSG is the Director of the *Laboratory for Applied Stochastic Processes*, a position from which he exerts a strong, stimulating influence on contemporary research in stochastics, informatics and nonlinear dynamics.

The aforementioned topics are only a bare smattering of the topical areas to which LSG has made fundamental contributions. He is thus widely known and highly esteemed by his colleagues and well-wishers the world over. Suffice it to look at the list of distinguished contributors to this volume in order to be convinced of the novelty, interest and impact of LSG's work over the past two and one-half some decades. And we can easily discern his influence extending over this time in the titles that comprise this volume, ranging as they do from stochastic resonance through noisy excitable systems, Brownian motion, to

[1] Having grown bored with treatises on linear systems in thermodynamic equilibrium, we seem to have adopted the rather unimaginative propensity to describe our main interests with *non-* words, delineating that in which we are definitely *not* interested in rather than troubling to identify that in which we are.

[2] Indeed, it took biologists and neuroscientists at least a decade and a half more (until the mid-to-late 90's) to begin to appreciate that noise – they insist on calling it "variability" - mediates many of the very processes of greatest interest in neurodynamics.

reaction-diffusion systems and structure formation; all topical areas to which Lutz has contributed.

We wish him well on his $50^{th}$ birthday and we look forward to an ensuing two or three more decades of inspiring and fundamental research.

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