# Preface

*To my family and my friends*
**Franz-Josef Schmitt**

*To my mother, my wife and my son*
**Suleyman I. Allakhverdiev**

This book introduces basic principles of light-matter interaction, photophysics, and photosynthesis in a brief manner in order to elucidate principles of complex signaling networks that enable spatiotemporally directed macroscopic processes. We will start with random walk processes typically used to describe excitation energy transfer in plant lightharvesting complexes and later focus on coupled systems such as the communication network of reactive oxygen species (ROS) which are embedded into the plant metabolism and enable an information transfer from molecules to the overall organism as a bottom up process. In addition the microscale dynamics always accepts signals on the bottom level that can be understood as a top down communication. One example is the activation of genes by ROS caused by macroscopic events like strong sunlight or atmospheric variations that activate a change in composition of the microscopic environment by producing new proteins.

Typical bottom up processes are cascades that start with gene activation and protein translation regulating plant growth and morphology. Top down messengers triggered by macroscopic actuators like sunlight, gravity, environment or any forms of stress, on the other hand, activate gene regulation on the molecular level and therefore concern the dynamics of single molecules under the constraints of macroscopic factors. In this book the generation and monitoring as well as the role of ROS in photosynthetic organisms as typical messengers in complex networks are primarily treated in a scientific manner. All findings are supported by our own research results and recent publications. Additionally, the principles of top down and bottom up messaging are presented in the form of a philosophical discussion.

The first chapter focuses on a theoretical approach according to the Principle of Synergetics (Haken, 1990) to understand coupling, networks, and emergence of unpredictable phenomena. The approach is used to model light absorption, electron transfer and membrane dynamics in plants. Special focus will be placed on nonlinear processes that form the basic principle for the accumulation of energy reservoirs and on the formation of forces that are able to control the dynamics of macroscopic devices.

The formalism of rate equations is presented as a general scheme to formulate dynamical equations for arbitrarily complex systems. Key is the definition of "states" as an intensity level or a pattern that carries a certain amount of information, and their dynamics which are assessed by evaluating the probability of transfer from one state to another. In fact, rate equations are not only used to describe energy transfer processes in photosynthesis but in many systems, for instance, optical transitions, particle reactions, complex chemical reactions and more general information processing in complex networks. Rate equations are also used to describe complex systems such as sociological networks.

The second chapter describes the basic principles of the light reaction in photosynthesis from absorption to the storage of free Gibbs energy in the form of energy rich chemical compounds. The roles of different processes that support light energy transduction, on the one hand, and non-photochemical quenching, on the other hand, are elucidated with special focus on the context of a highly adapted system that has developed as an advanced structure for energy conversion during evolution in its local environment.

In the third chapter the formation, decay, monitoring, and the functional role of ROS – mainly $H_2O_2$, $^1O_2$, $O^{\bullet}_2^-$ are described and the fourth chapter especially focuses on the messenger role of ROS. The ambivalent picture of oxidative degradation and signal transduction during exposure of oxygen-evolving, photosynthetic organisms to oxidative stress istelucidated. Both degradation and activation are important mechanisms of ROS signaling. Reaction schemes are presented for the formation and monitoring of ROS and their participation in stress signal transduction pathways both within prokaryotic cyanobacteria as well as from chloroplasts to the nuclear genome in plants. It is suggested that redoxregulated systems, mitogen-activated protein kinase cascades and transcription factor networks play a key role in the ROS-dependent signaling systems in plant cells and for their spatiotemporal morphology and lifespan.

Chapter five focuses on evolution. It is emphasized that mainly the local environment of evolving organisms enforces directed evolution resulting in quick changes of the phenotype if the genetic diversity of the organisms is large enough. In that sense leaps in evolution necessarily follow volatile changes of the environment. It might be possible that ROS are the most important driving forces in evolution.

The last chapter finally offers a glance at how the described concepts can be used to describe other biological principles and multiscale hierarchical systems in society, politics and economics. The book is intended for a broad range of researchers and students, and everyone who is interested in learning about the most important global process on our planet – the process of photosynthesis. We would like to believe that this book will stimulate future researchers of photosynthesis and lead to progress in our understanding of the mechanisms of photosynthesis and their practical use in biotechnology and in human life.

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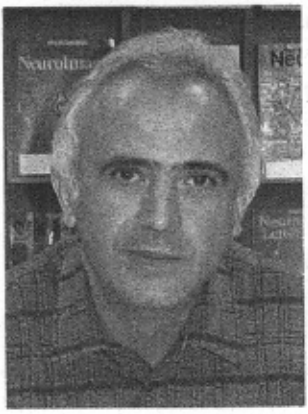

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