“Two are better than one: because they have a good reward for their labor … and a threefold cord is not quickly broken.”

Ecclesiastes 4:9, 12

Everything flows and nothing stands still, Sokrates says in the Kratylos dialogues (“Π ντά χωρε κα ο δ ν μ νεί’”). This insight holds particularly true today, more than ever before in the history of mankind. We face a profound change in our environment, due perhaps to changing natural habitats, overall pollution, or the induced climatic change. Our chances to escape this situation are very limited. Because we are able to create our own habitats such as cities, shopping malls, offices, etc., we are often distracted from the fact that – being highly organised metazoans – we are obligately associated and dependent on the stability of the living biosphere around us. As a matter of fact, game theoreticists describe preservation of the global climate as a huge public goods game. They also claim that it can only be solved by cooperative behavior, which is favored after we are better informed about the serious risks of planetary gambling (Dreber and Nowak, 2008). Under these premises, cooperation is in our own interest to maintain a symbiotic relationship with life on the Planet, and to persist as a species among so many others. The estimation of our impact and role will, hopefully, grow if we know more about the web of biological relationships, and the fragility or robustness of biotic networks under changing conditions. Symbiosis as a key concept in Biology is coupled with aspects of stress to reflect on this theme from diverse angles.

Symbiosis (derived from greek “sym”: together, and “biosis”: living) describes a situation in which two or more dissimilar organisms live together for an extended period of time. This wide-sweeping definition encompasses a continuum of organismal interactions, and is widely maintained in the international scientific community, although the connotation of mutual benefits prevails in public discussions. The term “Symbiotismus” was introduced by Frank (1877) in his study of crustose lichens and taken up as “Symbiosis” by de Bary (1879). In de Bary’s original sense of a living -together of unequally named organisms (“Zusammenleben ungleichnamiger Organismen”), the outcome of the interactions for either organism does not play a role and symbiosis also encompassed pathogenic interactions. Interestingly, de Bary quoted the parasitologist Van Beneden as using the term “mutualism” in a similar sense (the term mutualism thus predates symbiosis; see Van Beneden, 1873). Also, in the scientific community, symbiosis was then more frequently used for mutualistic interactions in which the participants benefit from the association (especially in German speaking countries), while symbiotic interactions with negative effects for one of the
engaging organisms were usually called pathogenic or parasitic. Today, we are aware that such value-laden terms are sometimes difficult to apply when interactions are weak or when they may change owing to varying external or intrinsic parameters. Douglas (1994) points out an evolutionary aspect and characterizes symbioses as long-term interactions that lead to new structures and metabolic activities.

Irrespective of the direct effects on the symbiotic organisms, symbioses are indeed major drivers of evolution. Intracellular endosymbioses, in which cells of one organism may have internalized symbiont cells into a host cell, led to the perhaps most important evolutionary innovation, the emergence of Eukaryota. The founder of this theory of symbiogenesis was Constantin Mereshkovsky (1855–1921). In the early decades of the twentieth century, he postulated that chloroplasts were symbiotic cyanophytes (cyanobacteria) and that the prokaryotic precursors of some eukaryotic organelles had been free-living organisms. Other examples of “living together” also include an enormous range of exosymbioses, where symbionts maintain their cellular integrity. The involved species maintain a close – usually physical – association, which can result in unique symbiotic morphologies. One of the richest, in terms of species numbers, of such symbioses are the lichens, traditionally seen as mutualistic symbioses between fungi and algae. Ecologically and economically very important are the mycorrhizal mutualisms of fungi with plants. Some plant groups also maintain bacteria in distinct root nodules of their hosts, but it is now known that specific bacterial communities are a common fraction on plant roots. Recent research has shown that many symbioses often involve more species than previously thought, and rather diverse organisms are involved in these symbiotic associations with variable degrees of specificity and interaction strengths. There are many other examples of well-studied symbiotic systems, such as the paramecia and green algae, plants and endophytic fungi, rhizosphere bacteria, and others that will be covered in this book. The list is virtually endless and a closer look will reveal new cases of symbiosis. New exciting cases of symbioses can be discovered in tropical rainforests, with their density of life, but even a walk outside in a park may lead to unexpected discoveries. One such case, perhaps, is the enigmatic presence of unicellular green algae in cells of the widely known park tree *Ginkgo biloba* (Tremouillaux-Guiller et al., 2002).

Stress involves a range of factors with harmful effects to organisms, which can cope with such unfavorable conditions by acclimatization or adaptation. Species have evolved protection and repair systems to tolerate stress in their environment. Stress responses have been studied in a wide range of organisms and at various levels of investigation, but still much work is required to understand the role of stress in symbiotic systems, which are so widespread on our planet. May stress facilitate the evolution of cooperation among unlike organisms, is stress naturally involved in the interaction of dissimilar species, and how do symbiotic systems cope with our changing environment? These and many more questions are pending further research. With this book we are attempting to promote research in this direction, the fascinating area of symbiosis and stress.
This volume is number 15 in the *Cellular Origins, Life in Extreme Habitats and Astrobiology* (COLE) series. It is a continuation and complement to the series volume 4 *Symbiosis: Mechanism and Model Systems* edited by J. Seckbach (2002). The purpose of this current collection is to present functional and evolutionary aspects of stress and mutually beneficial symbioses, i.e., the manifestation of biological cooperation among unrelated organisms. Mutualisms are ubiquitous in nature and may contribute to stress tolerance, ecosystem stability, and major evolutionary radiations. Rather than focusing on the particular organism groups involved, the structure of the book concentrates on general aspects. This includes metabolic processes, the structure of genomes in symbioses, evolutionary processes, and the ecology of symbioses. The 31 chapters contributed to this volume, by 60 scholars from a dozen countries, cover a variety of topics in the symbiosis and stress fields. The editors thank the authors for their contributions and their cooperation during the compilation of this book. We also acknowledge the efforts of many individuals for their careful reviewing of its chapters. We hope that the readers (whether they are biologists, ecologists, geneticists, or general readers interested in science) will extract new knowledge from this collection of articles.

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**References**

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