Preface

Extreme Biomimetics is a novel interdisciplinary scientific direction of modern biomimetics proposed for the first time in 2010; and is currently a vibrant area of research. It was born at the crossroads between such scientific disciplines as Prebiotic Chemistry and Mineralogy, Astrobiology, Evolutionary Biology, Hydrothermal Chemistry and Biochemistry, and Exobiology. These in turn include scientific directions such as the Primordial Soup Theory, the Origin and Evolution of Life, and Extreme Biomineralization (Fig. 1). To delve into these fields, radical rethinking was necessary, one that explores unusual and very unique chemical and biochemical scenarios. Such studies could lead to both a better understanding of the origin of life under harsh environmental conditions, and to new approaches for designing new composite materials with entirely novel physicochemical properties.

Today, Extreme Biomimetics is well on track as a powerful approach, and a milestone for modern biological materials inspired chemistry. This is particularly true where there is strong interest in the combination of various inorganic nano-organized structures with biological macromolecules; as well as using such macromolecules as templates and scaffolds. In contrast to traditional aspects of biomimetic synthesis of these hybrid materials at ambient temperatures, Extreme Biomimetics is based on mineralization and metallization of various biomolecules under conditions mimicking extreme aquatic niches like hydrothermal vents, geothermal pipelines, or hot springs with temperatures near boiling point. Here, organisms known as thermophiles, acidophiles, alkaliphiles, and polyextremophiles represent the sources for bioinspiration. Thus, the basic principle of this concept is to exploit biopolymers that are chemically and thermally stable under these very specific conditions in vitro.

Extreme Biomimetics also includes both chemical and biochemical reactions at very low temperatures—under so-called psychrophilic conditions—both in vivo and in vitro. In this case Extreme Biomimetics and Cryobiology, as well as Exobiology, are intimately intertwined. Processes which occur in deep-sea organisms defined as barophiles and piezophiles fall under the umbrella of Extreme Biomimetics.

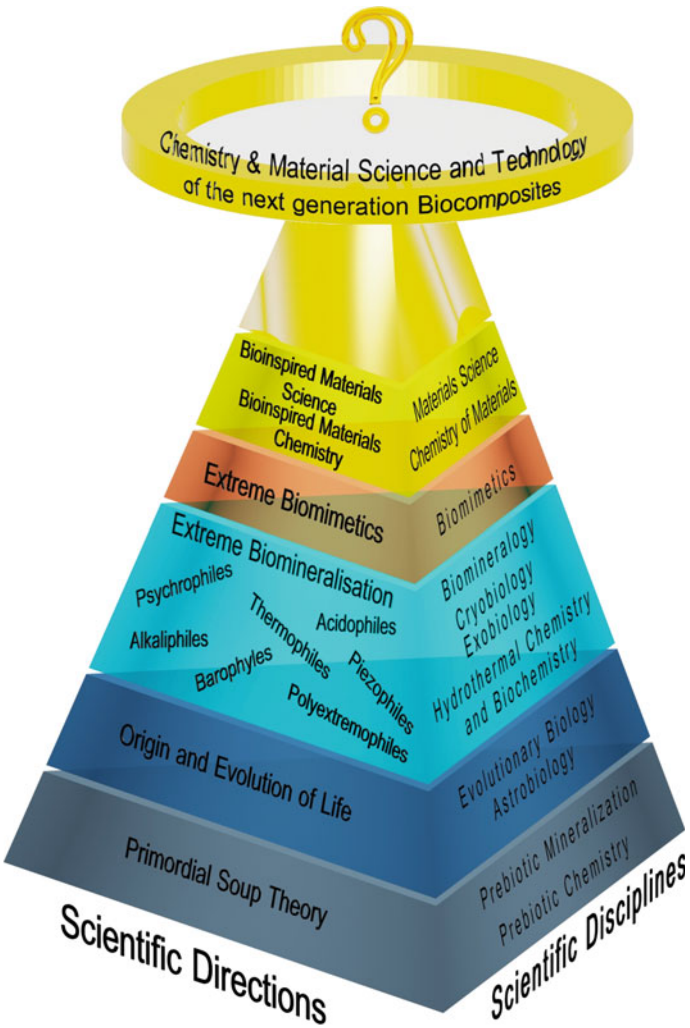

Fig. 1 Schematic view on the place of Extreme Biomimetics on the multidisciplinary crossroads

Thus, the goal of Extreme Biomimetics is to bring together broad variety of extreme (from the biological point of view) chemical reactions with templates of biological origin, and to develop the next generation of hybrid composites with novel properties.

At present, unfortunately, there is no monograph that deals with the area of Extreme Biomimetics and could, if required, serve as an accompaniment to a course of lectures on the subject. I sincerely hope that this book would be of interest for undergraduate and graduate students studying materials science, chemistry, bioorganic chemistry, biochemistry, solid-state physics, biophysics, bioengineering, and researchers, engineers, chemists, biologists, physicists, material scientists, and physicians. Therefore, the targeted audience of proposed book is broad variety of students and materials scientists associated with biocomposites, materials for medicine, biomaterials and hydrothermal technology.

This issue on Extreme Biomimetics illustrates how structures and functions of organisms that dwell under extreme conditions have inspired new forms of artificial biomineralization and technology. The book includes 135 figures, 11 tables and more than 1000 references. Authors from such countries as Germany, France, Japan, Poland, Russia, Ukraine, and the United States contribute to 10 chapters.

The collection of chapters begins with a review by Ehrlich and Nikolaev on psychrophiles as source for bioinspiration in biomineralization and biological materials science. They focus attention on biosilicification (in diatoms, silicoflagellates, radiolarians, sponges), and biocalcification (in bacteria, foraminiferans, sponges, bryozoans, corals, molluscs, echinoderms, crustaceans), and pay special attention to the biology and adaptation mechanisms of ice fish species. Additionally, these authors consolidate a wealth of references related to the topic that may be a time-saving resource for experts in materials science who are looking for model or key organisms as sources for special scientific and technological inspiration.

In continuation of this theme, Tabachnick, Janussen, and Menshenina look at a remarkable cold biosilicification process in psychrophilic glass sponges. In this chapter, the psychrophilic problem is discussed as it pertains to different aspects of the life cycle of hexactinellid sponges. New data on the vertical distribution of Hexactinellida is provided, which supports ideas put forth from previous investigations; as well as new interpretations of their mortal process. A new type of deep-sea reef construction of hexactinellid sponge *Sarostegia oculata* is described for the first time.

The next chapter prepared by Nikolaev and co-authors is logically dedicated to the phenomenon of psychrophilic calcification using artificial biomineralization methods. The first efforts to develop calcium phosphate-based composites on organic templates using a dual membrane diffusion method at the freezing point of water have been reported. Galkin and Sagalevich (Chap. 4) have contributed to an overview of hydrothermal vent fauna that represents a unique source for scientists who are involved in investigations of ecology, zoology, and biochemistry of extremophiles. Numerous unique underwater images represented in this chapter should help give a better understanding of the life near hydrothermal vents.

Comparative in situ microscopic observation of cellulose and chitin in hydrothermal conditions is described by Deguchi in Chap. 5. The experimental results reported here have direct ramifications for developing hydrothermal biomass conversion, hydrothermal synthesis of inorganic–organic hybrid composites, as well as fossilization of soft-bodied organisms. Boury (Chap. 6) takes inspiration from hydrothermal vent organisms and describes the integration of different biopolymers and a metal oxide under selective hydrothermal conditions, with the aim of developing new composites. This chapter emphasizes the important parameters of the synthesis, the impact of the biopolymers on characteristics of the metal oxide, and in improving its performance in technological applications.

Stawski in Chap. 7 paid special attention to the thermostability of chitin because of its potential application in hydrothermal synthesis, with the aim of creating novel nanostructured metal oxide-based composite materials. The author reported that chitin is still stable in the between 100 and 400 °C. Petrenko and co-authors (Chap. 8) propose a new term "bioelectrometallurgy," which they define as the electroplating of biological matrices. For the first time, cell-free chitinous sponge skeletons, which possess a 3D network structure, were used for copper plating under laboratory conditions. In Chap. 9, the unique structural, mechanical, and thermal properties of chitin from the "biomaterials" point of view have been discussed by Wysokowski, Kaiser, and Jesionowski. These authors also described the basic principles of solvothermal synthesis and utilization of chitin as a structural template in hydrothermal reactions. Finally, Szatkowski and Jesionowski (Chap. 10) analyzed the wide range of applications of the thermostable structural protein spongin of Poriferan origin in terms of its utilization in Extreme Biomimetics.

It may be sufficient to say that without enthusiasm and cooperation of all authors who have contributed to this first book on Extreme Biomimetics, this work could hardly have been attempted. I am very grateful to the German Research Foundation (DFG, Project EH 394/3-2) as well as to Krüger Research School, Biohydrometallurgical Center for Strategic Elements (BHMZ) at TU Bergakademie Freiberg, Germany, for financial support. I also thank Profs. Catherine Skinner, Edmund Bäeuerlein, Victor Smetacek, Dan Morse, Peter Fratzl, Matthias Epple, George Mayer, Christine Ortiz, Marcus Buehler, Andrew Knoll, Hartmut Worch, and Dirk-Carl Meyer for their support and permanent interest in our research on Extreme Biomimetics. To Dr. Allison L. Stelling, Dr. Mikhail V. Tsurkan and Sarah D. Smith-Tsurkan, I am thankful for taking excellent care of manuscripts and proofs. To my parents, my wife, and my children, I am under deep obligation for their patience and support during the years of my scientific activity.

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