METAL IONS IN LIFE SCIENCES

edited by

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VOLUME 4

Biomineralization. From Nature to Application

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Jossey-Bass, 989 Market Street, San Francisco, CA 94103-1741, USA

Wiley-VCH Verlag GmbH, Boschstr. 12, D-69469 Weinheim, Germany

John Wiley & Sons Australia Ltd, 42 McDougall Street, Milton, Queensland 4064, Australia

John Wiley & Sons (Asia) Pte Ltd, 2 Clementi Loop #02-01, Jin Xing Distripark, Singapore 129809

John Wiley & Sons Canada Ltd, 6045 Freemont Blvd, Ontario, Canada, L5R 4J3

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British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 978-0-470-03525-2

Typeset in 10/12pt Times by Integra Software Services Pvt. Ltd, Pondicherry, India
Printed and bound in Spain by Grafos S.A., Barcelona
This book is printed on acid-free paper responsibly manufactured from sustainable forestry in which at least two trees are planted for each one used for paper production.

The figure on the dustcover is Figure 1 of Chapter 2 by Fred H. Wilt and Christopher E. Killian.

Historical Development and Perspectives of the Series

Metal Ions in Life Sciences

It is an old wisdom that metals are indispensable for life. Indeed, several of them, like sodium, potassium, and calcium, are easily discovered in living matter. However, the role of metals and their impact on life remained largely hidden until inorganic chemistry and coordination chemistry experienced a pronounced revival in the 1950s. The experimental and theoretical tools created in this period and their application to biochemical problems led to the development of the field or discipline now known as *Bioinorganic Chemistry*, *Inorganic Biochemistry*, or more recently also often addressed as *Biological Inorganic Chemistry*.

By 1970 *Bioinorganic Chemistry* was established and further promoted by the book series *Metal Ions in Biological Systems* founded in 1973 (edited by H.S., who was soon joined by A.S.) and published by Marcel Dekker, Inc., New York, for more than 30 years. After this company ceased to be a family endeavor and its acquisition by another company, we decided, after having edited 44 volumes of the MIBS series (the last two together with R.K.O.S.) to launch a new and broader minded series to cover today's needs in the *Life Sciences*. Therefore, the Sigels' new series is entitled

Metal Ions in Life Sciences

and we are happy to join forces in this new endeavor with a most experienced Publisher in the *Sciences*, John Wiley & Sons, Ltd., Chichester, UK.

The development of *Biological Inorganic Chemistry* during the past 40 years was and still is driven by several factors; among these are (i) the attempts to reveal the interplay between metal ions and peptides, nucleotides, hormones or vitamins, etc., (ii) the efforts regarding the understanding of accumulation, transport, metabolism and toxicity of metal ions, (iii) the development and application of metal-based drugs, (iv) biomimetic syntheses with the aim to understand biological processes as well as to create efficient catalysts, (v) the determination of high-resolution structures of proteins, nucleic acids, and other biomolecules, (vi) the utilization of powerful spectroscopic tools allowing studies of structures and dynamics, and (vii), more recently, the widespread use of macromolecular engineering to create new biologically relevant structures at will. All this and more is and will be reflected in the volumes of the series *Metal Ions in Life Sciences*.

The importance of metal ions to the vital functions of living organisms, hence, to their health and well-being, is nowadays well accepted. However, in spite of all the progress made, we are still only at the brink of understanding these processes. Therefore, the series *Metal Ions in Life Sciences* will endeavor to link coordination chemistry and biochemistry in their widest sense. Despite the evident expectation that a great deal of future outstanding discoveries will be made in the interdisciplinary areas of science, there are still "language" barriers between the historically separate spheres of chemistry, biology, medicine, and physics. Thus, it is one of the aims of this series to catalyze mutual "understanding".

It is our hope that *Metal Ions in Life Sciences* proves a stimulus for new activities in the fascinating "field" of *Biological Inorganic Chemistry*. If so, it will well serve its purpose and be a rewarding result for the efforts spent by the authors.

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October 2005

Preface to Volume 4

Biomineralization. From Nature to Application

This volume is solely devoted to the vibrant research area around *Biomineralization*. The introductory chapter "Crystals and Life" sets the scene for the book. The "bio" in the term biomineral implies that the high activation energy (extreme temperature, pressure, etc.) commonly involved in mineral formation by strictly inorganic chemical means is bypassed by the intervention of biopolymers which alter the crystallization reaction pathways. Silicate minerals are most abundant but are restricted in the sense that the majority of silica biochemistry and biogenic siliceous mineral formation takes place in the oceans. The carbonate and phosphate cycles are more prominent in the terrestrial portion of the earth's surface as is also evidenced in several chapters of this book.

The interrelation between genes or genomes and biomineralization, as exemplified with calcium carbonate, and the role of enzymes in biomineralization processes are covered in Chapters 2 and 3. The ubiquity of prokaryotes (comprised of 'bacterial' and 'archeal' domains) is unparalleled in nature as pointed out in Chapter 4. These remarkable organisms have a metabolic plasticity and tolerance to extremes far greater than any other life form so that they are able to thrive in almost any terrestrial environment imaginable. They may form 'biofilms', i.e., matrix-covered bacterial populations that exhibit complex physico-chemical and physiological characteristics, which differ in their properties from planktonic cells in the overlying aqueous phase – and, yes, the biomineralization capacity of these minute creatures can have global effects!

Organisms exercize control over their mineral parts with great fidelity. So far over 60 different minerals are identified in all five kingdoms, calcium being the main, but not only, cation in biogenic minerals. This is evident from Chapters 5 to 7 where properties of carbonate, sulfate, and oxalate biominerals are summarized. The next chapter describes biosilicification processes in diatoms. These unicellular eukaryotic microalgae have emerged as a model organism for studying composites of organic material and nanostructured silica.

Chapter 9 is devoted to invertebrate tooth tissues containing large quantities of heavy metals for structural purposes. Examples include iron mineralized mollusk teeth, marine worm jaws with copper and zinc, or arthropod mandibles enriched with zinc and manganese. The next two chapters deal with biominerals in ferritins, which consist of nanoparticles formed by hydrated ferric oxide, and magnetotactic bacteria; these use magnetite or greigite in their magnetosomes which allow them to align and migrate along geomagnetic field lines, whereby each cell behaves as a self-propelled magnetic compass needle. Chapter 12 considers to what extent (bio)minerals are recorders of the past. This is a difficult question still open for debate because the role of bacteria in ancient geological formations, such as banded iron formations, is hard to establish since organic templates are rarely preserved, but even so, one is tempted to say yes.

The dynamics of biomineralization and biodemineralization are summarized in Chapter 13, the biodemineralization reactions being discussed for tooth enamel and bone. The skeleton of mammals and other vertebrates consists of a mineral phase (an analog of the geologic mineral hydroxyapatite) and an organic phase (principally collagen). Thus, Chapter 14 describes the mineralization mechanism of collagen-based connective tissues and the following one deals with mammalian enamel formation, enamel, a hard bioceramic, being the outermost cover of teeth.

Mineralized tissues such as bone, teeth, shells or glass sponges fulfill the mechanical functions of support or protection. As a consequence, these materials need to be very fracture-resistant and are therefore an ideal subject of study for biomimetic materials research as shown in Chapter 16. Similarly, the bioinspired growth of mineralized tissue, i.e., tissue engineering, the topic of Chapter 17, is an emerging discipline focused on generating tissue replacements using combinations of cells, biological molecules and materials. The terminating Chapter 18 deals with the controlled synthesis of inorganic crystals or hybrid organic-inorganic materials with specific size, shape, orientation, etc., and their incorporation into a structural hierarchy. With such building blocks new materials and devices can be designed for potential applications in diverse fields such as catalysis, medicine, electronics, ceramics or cosmetics.

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Contents

Metal Ions in Life Sciences links coordination chemistry and biochemistry in their widest sense and thus increases our understanding of the relationship between the chemistry of metals and life processes. The series reflects the interdisciplinary nature of Biological Inorganic Chemistry and coordinates the efforts of scientists in fields like biochemistry, inorganic chemistry, coordination chemistry, molecular and structural biology, enzymology, environmental chemistry, physiology, toxicology, biophysics, pharmacy, and medicine. Consequently, the volumes are an essential source for researchers Metal Ions in Life Sciences Vol. 5. Edited by Astrid Sigel, Helmut Sigel and Roland K. O. Sigel. prev. next.Â The general format ofthese chapters is to review the literature regardingthe structure, function, and gene organization/regulation of the species-specific MTwith compar-ison to the most well-studied mammalian MTs as apoint of reference. Chapters 1113 wrap up themetallothionein portion of the book with thefocused topics of brain-specific mammalian isoformMT-3, the function of metallothionein in metal -ionMetallothioneins andRelated ChelatorsMetal Ions in Life SciencesVol. 5. Edited by Astrid Sigel,Helmut Sigel and RolandK. O. Sigel.

In the present context, metal ions can be categorized into several classes including those that are essential for life and those that have no known biological function and thus can be considered only as potentially hazardous. Many complexities arise with regard to metal toxicity and there is a paucity of studies relating to many metals which are frequent components of the diet. January 14, 2019: Metal Ions in Life Sciences. https://read.qxmd.com/read/30855114/metal-compounds-in-the-development-of-antiparasitic-agents-rational-design-from-basic-chemistry-to-the-clinic. #2.Â With the impressive development of molecular life sciences, one may have the feeling that biopharmaceuticals will dominate the world of drug design and production. This is partly due to the evolution of pharmaceutical industry, especially since the 1980s. As a matter of fact, small molecules are still dominating the field of drug innovation, in contradiction with claims predicting their downfall and the exponential raise of biopharmaceuticals. Metal-Carbon Bonds in Enzymes and Cofactors Volume 6 The occurrence of a wide variety of metal-carbon bonds in living organisms, ranging from bacteria to humans, is only recently appreciated. Of course, the historical examples are the B12 coenzymes containing cobalt-carbon bonds, but now such bonds are also known for nickel, iron, copper, and other transition metal ions. There is no other comparable book; MILS-6, written by 20 experts, summarizes the most recent insights into this fascinating topic. Metal-Carbon Bonds in Enzymes and Cofactors Volume 7 This volume, closely related to MILS-6, de