BIOLOGICAL MINERALIZATION

EDITED BY

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Biological Mineralization

This volume is dedicated to the memory of my parents

ABRAHAM and BLUMA

and to my family

LILLIAN, RICHARD, and MICHAEL

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Preface

A number of reviews and symposia have been written for the scientist with a deep esoteric interest in various phases of biological mineralization. Indeed, specialists have developed specific areas of the anatomy, physiology, biochemistry, and biophysics of the "hard tissues," and learned treatises have been presented as a result of these studies. The major objective of this volume is to present these and related aspects of mineralized tissues in a language and style that would appeal to the student and the academician whose field is not mineralization. It is intended for the scientsist who desires to broaden his perspectives to encompass a field foreign to his central interest, but in which he has a reading of peripheral interest. Hence, an attempt has been made to deal with the basic concepts and to minimize the details.

The volume opens with a chapter on apatite as a possible template for life; that is, the primordial material for the evolution of living matter. Part Two deals with the inorganic and organic composition of bones and teeth as well as with the enzymes and hormones concerned with mineralization. Part Three treats the methodologies concerned with the biophysical properties of bones and teeth. Thus the ultrastructure of bones and teeth at the electron miscroscope level is presented. Such biophysical techniques as x-ray diffraction, infrared and electron spin resonance, as well as autoradiography and microradiography are presented to give some relevance of structure to function. Part Four is concerned with the role that such specific elements as strontium, manganese, copper, zinc, calcium, phosphorus, magnesium, and fluoride may play in the nutritional bicohemistry of bone.

Part Five describes some unique mammalian calcification patterns as seen in the fetal hard structures, in fossils, and in dental calculus. In addition, a type of ectopic calcification as seen in calciphylaxis and calcergy is discussed. Calcification in such nonmammalian systems as plants, bacteria, and protozoa is described in Part Six wherein apatite formation may (bacteria and protozoa) or may not (plants) play an important role. In the interests of brevity, such nonapatitic calcification patterns as found in most marine invertebrates are not discussed. "Calcification" involves a specific role of

calcium in the construction of a hard tissue so that "mineralization" would be a more general term. Indeed, the diatom prefers to use silicon rather than calcium for its supporting structure. This particular type of mineralization could then be more specifically called "silicification."

The last three parts deal with more general considerations in the physiology of bone. Thus Part Seven is concerned with balance studies in the human under physiological stress involving elements intrinsically related to mineralization. In a companion chapter, the effect of mechanical stress on clinical growth and development of bone in the experimental animal is presented with relevance to the dental discipline of orthodontia. Part Eight deals with various inducers and inhibitors of calcification, whereas the last part is concerned with the kinetics of calcification as related to both nucleation and to turnover rates.

It is hoped that this volume will appeal to the serious scientist whose field is not calcification (or mineralization), and that he will find a leisurely perusal of the various chapters to be both interesting and enjoyable.

I. ZIPKIN

San Francisco, California
June 1972

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for the Origin of Life

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ONE In the Beginning There Was Apatite

W. F. NEUMAN* and M. W. NEUMAN*

I. INTRODUCTION

Was there ever a child who, at some troubled moment in his search for selfhood, did not ask, "Mommy, where did I come from?" And was there ever a parent, after stumbling through the story of the "birds and bees," who

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himself did not wonder: "Yes, but where did *we* come from?" and continue from there to: "Where and how did life arise?"

The origins of life is one of the ubiquitous questions which have plagued man since he became aware of the transience of life and his own limited mortality. For eons of time, man had to content himself with answers derived from myths and inspired revelation. But today, in our teeming technological world, he is prone to turn to the modern muse, Science, for gratifyingly hard, factual answers to such troubling questions. Unfortunately, as we shall show, Science has no hard, factual answers. Rather, there exist an array of possible answers of undertermined probability such that the layman and the professional alike can more or less choose what be wishes to believe. Because this situation exists and because this chapter introduces a collection of works on biological mineralization, we choose to believe that: "IN THE BEGINNING THERE WAS APATITE."

This idea, that apatite crystals may have performed a crucial role in prebiotic evolution, requires a contextual setting. However, because the period of scientific thought on the origins of life is very short, so also will be its historical review.

II. HISTORICAL (1–3)

From ancient times until the late nineteenth century, all great thinkers subscribed to the cult of Spontaneous Generation. It was generally believed that all sorts of living things (insects, worms, frogs, mice, and even crocodiles!) could arise *de novo* from rotting materials (the less attractive, the better!). There even developed recipes for generating life, the most famous being that of van Helmont for making mice from wheat and soiled underwear.