2nd edition

The Biochemistry and Physiology of Bone

volume II

Physiology and Pathology

edited by Geoffrey H. Bourne

Academic Press

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SECOND EDITION

Edited by GEOFFREY H. BOURNE

Yerkes Regional Primate Research Center
Emory University
Atlanta, Georgia

VOLUME II

Physiology and Pathology

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Contributors

N. A. Barnicot

Geoffrey H. Bourne

D. Harold Copp

Robert J. Cousins

S. P. Datta

Hector F. DeLuca

Reuben Eisenstein

Frederic W. Rhinelander

Marshall R. Urist

Alfred Weinstock

List of Contributors

Numbers in parentheses indicate the pages on which the authors' contributions begin.

N. A. Barnicot (197), Department of Anthropology, University College London, London, England

Geoffrey H. Bourne (79, 231), Yerkes Regional Primate Research Center, Emory University, Atlanta, Georgia

D. Harold Copp (337), Department of Physiology, University of British Columbia, Vancouver, British Columbia, Canada

Robert J. Cousins (281),* Department of Biochemistry, University of Wisconsin, Madison, Wisconsin

S. P. Datta (197), Department of Biochemistry, University College London, London, England

Hector F. DeLuca (281), Department of Biochemistry, University of Wisconsin, Madison, Wisconsin

Reuben Eisenstein (357), Division of Pathology, Presbyterian-St. Luke's Hospital, Chicago, Illinois

Frederic W. Rhinelander (1), Cleveland Metropolitan General Hospital, Cleveland, Ohio

* Present address: Department of Animal Science, Rutgers University, New Brunswick, New Jersey

MARSHALL R. URIST (155), Bone Research Laboratory, Rehabilitation Center, Los Angeles, California

ALFRED WEINSTOCK (121),* Department of Anatomy, McGill University, Montreal, Canada, and School of Dentistry, and Department of Anatomy, School of Medicine, University of California, Los Angeles, California

* Present address: Departments of Periodontology and Anatomy, Schools of Dentistry and Medicine, University of California, The Center for the Health Sciences, Los Angeles, California

Preface to Second Edition

The first edition of this treatise filled a long-existing gap. It found an immediate place on the library shelves of anatomists, orthopedists, biochemists, cell biologists, physiologists, biomedical engineers, and others who had anything to do with this hard but plastic, living, and contentious tissue. The book appealed to graduate students and professors, pathologists and clinicians, and in many places of the world became a standard work.

This second edition, appearing fifteen years after its predecessor, has expanded into a three-volume work, attesting to our growth of knowledge in many aspects of this field. Volume I, dealing with structure, covers the nature and behavior of bone cells, the structure of the organic matrix of bone, mineral organization, and bone strength. Volumes II and III deal with the blood vessels which nourish bone, the mechanisms of bone formation, bone growth, repair, and transplantation, and the role of hormones and vitamins in the formation and maintainance of bone. Pathological calcification and radiation effects on bone complete each of these volumes. We believe we have matched the first edition in interest and importance and hope it will appeal to as diversified an audience.

I would like to thank the contributors for their cooperation and courtesy and for their hard work and enthusiasm. To the staff of Academic Press I owe many years of cooperation, forebearance, and understanding.

GEOFFREY H. BOURNE

Preface to First Edition

In the last 25 years there has been a rapid development of new techniques and enthusiasm in their application to bone studies. A store of new knowledge has been accumulated about structure and function of bone and a growing appreciation of the skeleton as a plastic, actively metabolizing tissue. Papers dealing with these and other aspects of bone are published in an astonishingly wide range of journals throughout the world. The present treatise is the outgrowth of a belief that the time had come to collect these diverse studies into an integrated volume. Its comprehensiveness should make it of interest to many experts, in particular to histologists, to anatomists, to specialists in orthopedics and pediatrics, and to dentists; in addition I hope that many biologists, physiologists, biochemists, and pathologists will find a great deal of interest and value to them between its covers.

The study of bone has passed through a number of phases. Many of the older workers were well aware of the plastic nature and metabolic activity of bone, but later a tendency to regard bones as immutable structures that one could cut and shape and treat as inanimate building material became widespread.

Frey, in his manual of histology, published nearly 100 years ago, summarized what was until relatively recently thought to be the function of bones: "Owing to their hardness and solidity, the bones are peculiarly well adapted for the mechanical construction of the body. . . . They serve to protect internal organs, and form systems of levers." But Frey also goes on to say "The bones take part also, to a great extent, in the chemical occurrences of the organism, owing to the lively interchange of matter going on in them." This is, in fact, a modern outlook on bone.

To some extent it was the mechanical investigations of bones by engineers such as Carlmann and Kochlin which tended to emphasize

their structural nature and to suggest a permanence which was illusory; in fact it has been said that Kochlin designed the struts for the Eiffel tower on the same plan as the trabeculae at the head of a long bone (first described by Meyer in 1873). The bone struts of course can do what those of the Eiffel tower cannot; they can be altered in shape, size, and direction with varying stresses and strains and this is one of the characters which most distinguishes bone from an inert supporting structure.

In the last hundred years investigation of bone has proceeded actively in a wide variety of fields and in the present century the development of biochemistry has contributed a good deal to our knowledge of the nature of the organic matrix, the problems involved in calcification, and so on. The influence of vitamin deficiency on bone is well known but recent research has helped towards an understanding of the mechanism by which such changes are brought about. More recently a great deal of attention has been paid to the role of hormones in bone formation and structure. The cells of bone and problems of bone development and repair have been extensively studied. Probably the most recent field is the application of radioisotopes to the study of bone structure and function.

It would be too great a feat to expect any one person to deal comprehensively with all these facets of bone study and therefore the best solution was found to be a composite book.

In such a book a certain amount of planned overlap of chapters is both inevitable and desirable. Chapters which deal, for example, with osteoblasts, phosphatases, and calcification must be expected to have a good deal in common; in the same way the growth of bone would naturally be discussed in chapters other than that bearing such a title. In fact, one can think of this book, in a sense, as a spectrum, each of the chapters representing a pure spectral color but shading indistinguishably into its neighbors.

The collecting together, on time, of 24 chapters by authors scattered over Europe, America, and the Middle East seemed an intimidating task but thanks to the cooperation and hard work of all who participated in this volume it proved to be by no means as difficult as it seemed at first.

My thanks are due to all, authors and staff of Academic Press, for their help in bringing together and getting into print so promptly the mass of material contained in this book.

GEOFFREY H. BOURNE

London Hospital Medical College
February, 1956

Contents of Other Volumes

VOLUME I: Structure

VOLUME III: Development and Growth

Contents

Chapter 7. **Vitamin D and Bone**

Robert J. Cousins and Hector F. DeLuca

Chapter 8. **Calcitonin**

D. Harold Copp

Chapter 9. **Pathological Calcification**

Reuben Eisenstein

CHAPTER 1

Circulation in Bone

FREDERIC W. RHINELANDER

I. Introduction

A. Importance of Knowledge of Bone Blood Supply

All of the physiologic processes within bone are dependent upon the presence of an adequate blood supply, and alterations in this blood supply can profoundly affect any of these processes. When a bone is injured, the vascular response is an essential consideration in treatment and it greatly affects the final result.

The chemical and cellular responses of bone's many constituents, under normal and under pathologic conditions, have been studied extensively. However, investigations of the essential blood supply have been relatively few. Those that have been carried out are well reviewed, with bibliographies, by Trueta (1964) and Brookes (1964). The review by Brookes will be drawn upon particularly in the ensuing presentation.

In discussions of bone blood supply, the so-called long bone is the generally used model because it is a fundamental component of the mammalian skeleton and it encompasses the chief types of osseous tissue. At the outset, a clear understanding of a long bone's basic anatomic features is essential for an analysis of its complex vascular patterns to be comprehensible.

B. Anatomy of a Long Bone

The long bone is the major unit of the appendicular skeleton. It consists basically of a shaft (diaphysis) with an expansion (metaphysis) at each end. An idealized long bone is illustrated in Fig. 1.

In an immature animal, each metaphysis is surmounted by an epiphysis which is united to its metaphysis by a cartilaginous growth plate (epiphyseal plate). At the extremity of each epiphysis, a specialized covering of articular cartilage forms the gliding surface of the joint (articulation) which provides motion between the particular long bone and the adjacent bone in the skeleton.

The diaphysis is a hollow tube. Its walls are composed of dense cortex