THE BODY FLUIDS

BASIC PHYSIOLOGY & PRACTICAL THERAPEUTICS

J. R. ELKINTON, M.D. *and* T. S. DANOWSKI, M.D.

The Body Fluids

BASIC PHYSIOLOGY AND PRACTICAL THERAPEUTICS

J. RUSSELL ELKINTON, M.D.

Associate Professor of Medicine, Chief of the Chemical Section of the Department of Medicine, University of Pennsylvania School of Medicine. Ward Physician, Hospital of the University of Pennsylvania.

T. S. DANOWSKI, M.D.

Renziehausen Professor of Research Medicine, Senior Staff Physician at the Children's, Presbyterian-Women's, and Elizabeth Steel Magee Hospitals, University of Pittsburgh School of Medicine.

THE WILLIAMS & WILKINS COMPANY

BALTIMORE — 1955

Made in the United States of America

Reprinted July, 1956

Library of Congress
Catalog Card Number
55-9340

COMPOSED AND PRINTED AT
THE WAVERLY PRESS, INC.
BALTIMORE 2, MD., U. S. A.

The Body Fluids

To our teachers and to our many colleagues, and especially to

JOHN P. PETERS and ALEXANDER W. WINKLER

PREFACE

During the past three decades many advances in medical science have profoundly changed the nature of medical practice. Of these advances one of the most far-reaching has been the application of laboratory methods to the diagnosis and treatment of sick people. This has come about through the development of chemical methods for the analysis of biological materials, and through an increased interest in the application of concepts of basic physiology and biochemistry to the study of the diseased organism. The results of this development have been mutually beneficial to the basic sciences and clinical medicine and have greatly increased our knowledge of disease processes and our ability to deal with them. But it has also resulted in the fact that the physician is faced with an enormous and steadily increasing amount of physiological information and with complex chemical tools for diagnosis and treatment. He also finds some diversity of opinion among the experts in regard to the use of these chemical tools. It is not surprising, therefore, that physicians old and young admit to a certain amount of confusion in their attempts to master these tools for use in their profession, and express a need for help in separating the more important from the less important and proved fact from mere opinion.

This monograph is an attempt to meet this need in respect to one field of clinical medicine, namely, disturbances of body fluid dynamics. No book by one author or group of authors can cover this subject either completely or finally, for new knowledge is constantly being acquired and fresh insight gained. Furthermore, the range of clinical disturbances included in this subject is so wide that the clinical experience of no two groups of authors is likely to be identical. Nevertheless, because of the need stated above, it seems worthwhile to attempt to summarize present knowledge in the field and in the light of this knowledge to analyze the experience of one group of workers.

The plan of the monograph is to present first a discussion of fundamental concepts of physiology and biochemistry in this field, utilize these principles in presentation of common denominators in clinical problems, discuss specific disease entities, and end with practicalities in assessing and correcting disorders of body fluids. In this way it is hoped that the book will be of value both to the student of physiology and to the clinician seeking practical help in the treatment of his patients; to the former it may serve, at least, as an annotated bibliography.

We are grateful to our many colleagues, past and present, at the University of Pennsylvania and the University of Pittsburgh, whose critical

judgment was helpful in the preparation of this volume. In particular we wish to acknowledge the assistance of Doctors E. S. Barker, L. W. Bluemle, Jr., J. R. Brobeck, T. M. Chalmers, J. K. Clark, E. B. Fergus, L. Greenman, A. G. Hills, K. Hofmann, E. J. Huth, M. Iunes, F. M. Mateer, F. H. McCutcheon, I. A. Mirsky, C. Moses, Jr., J. H. Peters, J. E. Rhoads, B. Shapiro, R. B. Singer, R. D. Squires, W. C. Stadie and F. A. Weigand.

The preparation of this volume would not have been possible without the devoted assistance of our secretaries: G. Bowers, A. D. Francis, M. B. Kyle, E. M. Roedel, and C. M. Whiteley. The copy was assembled by P. Wirth and the manuscript was checked by E. Trotter.

To our respective families we owe much for their forebearance and ever-present moral support.

Finally the authors wish to indicate their indebtedness for the financial support which was received from the Established Investigatorship of the American Heart Association (J. R. E.) and the Guggenheim Fellowship (T. S. D.) during the preparation of this text.

Philadelphia and Pittsburgh, Penna.
April, 1955

J. R. E.
T. S. D.

Historical Preface

In the field of body fluid physiology, as in all other realms of knowledge, the achievements of the present rest firmly on the foundations of the past. Although the authors of this volume have made no attempt to review the subject in a historical manner, they wish to acknowledge their indebtedness to the pioneers of the past and to their contemporary colleagues who have obtained the data, developed the concepts, and made available the knowledge with which this book has been written.

The history of this field of endeavor may be divided conveniently into three periods of development: the century preceding World War I, the period between World Wars I and II (1918–1941), and the present period which began a little more than a decade ago during the last war. In the first of these periods, parenteral fluid therapy was pioneered by O'Shaughnessy and Latta (1832), biochemical analyses of the body fluids were begun by Schmidt and Bidder (1850), and physiologic concepts were developed and data obtained. The latter included the classic concept of *le milieu intérieur* as first promulgated by Claude Bernard in 1859, and the reciprocity of sodium and potassium transfers as observed by Bunge in 1873. The development of adequate analytical methods by such biochemists as Folin, Van Slyke, and Benedict prepared the way for the second period.

The period between the wars was perhaps ushered in by L. J. Henderson's contributions, in the field of physiological chemistry, to the understanding of the body's defence of neutrality, and by the application of that knowledge by Van Slyke, Peters, and others to clinical problems. This was the period of the birth and development of the field of clinical investigation in which such workers as Peters, Van Slyke, Gamble, Hartmann, Aub, Albright, Loeb, Butler, Newburgh, Darrow, McCance and many others brought the tools and concepts of the laboratory to the bedside of the patient. At the same time, in the disciplines of the so-called *basic sciences* of biochemistry and physiology, great advances were made in the understanding of the dynamics and regulation of the body fluids by such workers as Starling, Govaerts, Macallum, Adolf, Krogh, Richards, Landis, Hastings, Smith, Visscher, Conway, Gilman and others.

With the advent of World War II and the development of atomic energy, the study of water and electrolytes began a new era. This era has been characterized by a tremendous expansion of research activity. In 1934, 10 and 38 papers on subjects in this field appeared in the Journal of Clinical Investigation and the American Journal of Physiology, respectively;

in 1954 the corresponding numbers were 50 and 82 papers. This expansion has been due, at least in part, to the development of the flame photometer for the rapid determination of sodium and potassium and to the availability of radioactive isotopes for use as tracer constituents in the body fluids. The names of our contemporary fellow-workers in this field are too numerous to mention individually but will be found in the bibliographies throughout the book.

Prophecy has no place in a historical note but it would appear that we are on the threshold of a tremendous advance in knowledge of the fundamental processes of body fluid dynamics and in the application of that knowledge to the diagnosis and treatment of sick people. It is the hope of the authors that the present volume may assist this advance in knowledge and may contribute to the care of patients which will result from the application of that knowledge.

CONTENTS

PART I. BASIC PHYSIOLOGY

Chapter 1. Body Fluid Dynamics

Chapter 2. Paleochemistry, Evolution, and Comparative Physiology of the Body Fluids

Chapter 3. Methods of Studying Body Fluid Distribution

PART II. BASIC PRINCIPLES AS COMMON DENOMINATORS IN CLINICAL SITUATIONS

Chapter 4. The Water and the Electrolytes of the Body in Health

Chapter 5. Mechanisms which Guard the Volume and Composition of the Body Fluids in Health

Chapter 6. Common Denominators in Disease States Leading to Deficits of Body Constituents

Chapter 7. The Physiologic Effects of Water and Electrolyte Deficits and Their Treatment

Chapter 10. Anion-Cation Balance and pH: Physicochemical and Physiological Mechanisms

Chapter 11. Anion-Cation Balance and pH: Clinical Disturbances and Their Treatment

PART III. DISEASE ENTITIES

Chapter 12. Renal Failure

Chapter 13. Congestive Heart Failure: A New Steady State

Chapter 14. Cirrhosis and Ascites

Chapter 15. Diabetic Ketosis and Coma

Chapter 16. Familial Periodic Paralysis

Chapter 17. Water and Electrolyte Changes in Relation to the Anterior Pituitary, Thyroid, Gonads, and the Pancreatic Islets

Chapter 18. Hypo- and Hyperfunction of the Adrenal Cortex