

# Quantitative Acid-Base Physiology

System Physiology and Pathophysiology of Renal,  
Gastrointestinal, and Skeletal Acid-Base Metabolism

by

POUL KILDEBERG



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For this generous support and for numerous helpful discussions with mag. scient. Knud Engel, Institute of Clinical Chemistry, Odense University, and professor Robert W. Winters, Department of Pediatrics, Columbia University, New York, I am deeply grateful.

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December 1980



# Preface

Any approach to acid-base metabolism in system physiological terms such as rates of gain and loss, distribution, concentration, turnover, exchange, control, and regulation immediately raises the question of the specificity, in an organ-physiological sense, of conventional objects of measurement. Among the latter, only the stoichiometric concentration of carbon dioxide in body fluids has proven physiologically specific; and consequently our understanding of the role of the lung in overall acid-base metabolism greatly surpasses our understanding of those of other organ systems. It has therefore been a primary object of this work to examine closely possible concepts of *amount* and *kind* of 'acid' and 'base' in order to identify measurable acid-base components with the same kind of organ-physiological specificity in regard to the function of such systems as characterizes carbonic acid in regard to pulmonary function. To the organism, hydrogen ions are all alike; and on principal grounds differences in physiological behavior between particular hydrogen ions must be determined by the behavior of the different anions by which they are accompanied and by that of the different cations for which they are exchanged. It follows from this simple statement that physiologically specific kinds of 'acid' and 'base' must be defined in terms of groups of ionic conjugates of molecular Brønsted acids and bases. This approach serves to reconcile the older medical 'anion-cation' terminology and the Brønsted-Lowry definitions which in regard to fundamental concepts are essentially identical.

The main theses of the present volume are the following: (1) An amount of acid should be defined as the sum of changes in extent of partial acid-base reactions required to reach an arbitrary reference state for the components of the system concerned; (2) an amount of acid so defined can be expressed as the sum of amounts of acid represented by each component buffer system or, alternatively, as the sum of amounts of acid contributed by any complete collection of non-ionic stock components of the actual system in its reference state; (3) operationally, the latter approach allows the physiologist to distinguish between specific *sources* of acid and base in terms of acid-base reactions of relevance to the problem considered; (4) hydrogen ions subject to flux with bicarbonate ions, metabolizable anions, and non-metabolizable anions, respec-

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tively, display entirely different physiological characteristics; (5) the contribution to the concentration of acid in body fluids represented by hydrogen ions associated with non-metabolizable anions (or exchanged for non-metabolizable cations) is substrate specific with respect to *gastro-intestinal*, *skeletal*, and *renal* acid-base metabolism; (6) overall acid-base metabolism can be described quantitatively in system physiological terms based on the concept of a three-circuit pH-stat mechanism operated within limits set by organ capacities, quality of organ function, and set-point fluctuations; and (7) any aberration of the extracellular acid-base status must be analyzed in terms of sources of concentration change, viz., changes in balance, distribution, and/or solvent volume, and maintenance of concentration change by specified changes in the functional state of the control organs involved.

The book is intended for physiologists, clinical chemists, and clinicians who wish to gain insight in the organ physiology of acid-base metabolism at a fairly advanced level. The selection of references has been dictated by the specific topic; and for more complete bibliographical information on the clinical-chemical, biochemical, and medical aspects of acid-base metabolism the reader may consult the monographs by Siggaard-Andersen (1974), Hills (1973), and Kildeberg (1968).

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