

Morphometry of the Human Lung

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With a Foreword

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With 109 Figures



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C'est à vous, cher maître,
Que je voue cet oeuvre.
Vos pensées en étaient les racines –
Par votre génie lui pousseront des fleurs.
J'espère que le tronc et les tiges vous plaisent.

TO MY MASTER AND FRIEND
DOMINGO M. GOMEZ

Foreword

The work presented in this monograph marks a new era, we believe, both in the development of quantitative anatomy of the lung, and in the correlation of anatomy with physiology.

For many years, physiologists interested in the overall functioning of the lung have felt a need for better quantitative descriptions of pulmonary anatomy. As physiologists, we know a good deal about the forces operating to produce pulmonary ventilation, and the quantities that define this function in rest and exercise; and the same for effective distribution of air within the lung — “alveolar” ventilation —, and for the exchange of respiratory gases between air and blood. There have been no correspondingly precise quantitative measurements of the pulmonary structures that serve these functions.

The great advances in the study of pulmonary anatomy in the past decade have been chiefly in the realm of “fine structure”. This has tended to bring together anatomy and biochemistry or physical chemistry, rather than anatomy and physiology. This conjunction has aided, for example, the conception of diffusion as a physicochemical process, but not that of diffusion as a metabolic bodily function.

It was, therefore, a remarkably fortunate circumstance which brought together in our laboratory, about three years ago, Professor DOMINGO GOMEZ and Dr. EWALD R. WEIBEL: Professor GOMEZ a mathematician and biophysicist of distinction and long experience; Dr. WEIBEL a young anatomist trained under Professor GIAN TÖNDURY in Zürich, and with additional research experience with Professor AVERILL LIEBOW at Yale.

As the pages of this monograph will set forth, an entirely new methodology for quantitative description of a complex organ has been developed. To Dr. WEIBEL's own industry and imaginative effort are due new methods of preparation of tissues, new methods of random sampling, and adaptation of methodologies from other fields of science. His collaboration with Professor GOMEZ has led to original mathematical formulations for the translation of the data into the desired geometric forms and a new technique of counting. — Briefly summarized, this work has resulted in reliable information as to the size and number of the basic elements of pulmonary anatomy. More precision as to their number, dimensions, mode of distribution and geometric forms, should eventually facilitate mathematical and physical considerations regarding the function of the lungs. Application of these quantitative methods to the study of pathologic specimens will also provide a most timely renovation of morphologic pathology.

This new era which Drs. WEIBEL and GOMEZ have initiated in the precise quantitative description of the anatomy of the lung, may well be equally applicable to the study of other organs, and may thus eventually establish a broad community of interest between anatomy, pathology, and physiology.

It has been a privilege to have Dr. WEIBEL as one of our research associates for two years, and most gratifying to have had this important work originated and carried out in the Cardio-Pulmonary Laboratory of the Columbia University Division at Bellevue Hospital.

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DICKINSON W. RICHARDS

New York, March 1963

Preface

In discussing with physiologists possible relationships between structure and function of an organ such as the human lung, a morphologist often feels that he speaks a language different in accent and sometimes in vocabulary from that of his colleagues of the other discipline. What appears most interesting — and therefore most important — to him, may be only of secondary significance to the physiologist. In part this may be due to the fact that a morphologist is inclined to marvel at the diversity of structures used to build an integrated organism, while the physiologist will tend to seek general and simple laws underlying complex events, even if this is possible only in the sense of a first and crude approximation.

Intrigued by this apparent incongruity of the goals of pulmonary morphologists and physiologists in particular, I welcomed the prospect of collaborating as a morphologist with a group of outstanding physiologists, and I am most grateful to Dr. ANDRÉ F. COURNAUD and Dr. DICKINSON W. RICHARDS for arranging this unusual opportunity for me. While I worked in the Cardiopulmonary Laboratory of Columbia University at Bellevue Hospital they generously supported and stimulated the development of a morphologic study on the lung, whose original goals were necessarily quite obscure. In the course of numerous discussions with their group a long-range program finally evolved: it asked for the search of general principles underlying the structural organization and determining the functional adequacy of the human lung. This appeared to be best achieved through a systematic quantitative analysis of pulmonary structures.

At this point I wish to express my very special gratitude to Dr. DOMINGO M. GOMEZ, to whom this book is dedicated. He actually guided the development of this work onto and along the path it eventually took by first asking the right questions, and then lending a generous helping mind when their answer was to be sought. His role in this work is ubiquitous and cannot be overappreciated. I hope, moreover, that his influence will be a lasting one.

I also wish to acknowledge my sincere gratitude to Dr. GEORGE E. PALADE for allowing me to work and learn in his Department of Cytology at The Rockefeller Institute during this last year and for generously supporting and stimulating the continuation of these studies at the cellular and subcellular levels. I would like to thank Mr. BRUCE W. KNIGHT, Affiliate at The Rockefeller Institute, for his cooperation in the development of necessary measuring principles during this period.

I am thankful to the following granting institutions for supporting this work with generous funds: to the National Institutes of Health for awarding me a Research Fellowship (FFG-47); to the Health Research Council of the City of New York for granting me two Investigatorships (I-126 and I-188); to the New York Heart Association for a Research Grant. Further funds were provided through Training Grant H-2001 of the National Heart Institute, National Institutes of Health, to the Cardiopulmonary Laboratory at Bellevue Hospital.

Finally I wish to express my sincere appreciation to those who enhanced the progress of this work in many ways: to Mrs. BARBARA B. FRANK for her enthusiastic assistance; to Dr. AVERILL A. LIEBOW, Dr. THANE ASCH and Dr. ISRAEL STEINBERG for allowing me to use some of their preparations; to Miss JEAN SEIBERT, Miss CHRISTINE ROSNER and to my wife for helping me with the preparation of the manuscript; to Dr. CHARLES E. LYGHT and Mrs. LOUELLA NIGH for revising the text; and to all my colleagues for numerous suggestions and criticisms.

New York, June 1962

E. R. W.

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