Human Respiration: Anatomy and Physiology, Mathematical Modeling, Numerical Simulation, and Applications. V Kulish, editor. *Advances in Bioengineering* series, volume 3. Billerica, Massachusetts: WIT Press. 2006. Hard cover, illustrated, 218 pages, $150.

The title, **Human Respiration: Anatomy and Physiology, Mathematical Modeling, Numerical Simulation, and Applications,** promises a breadth of pulmonary subject matter that could be difficult to fulfill within 10 chapters. Parsing the title, "Anatomy and Physiology" is obvious; "Mathematical Modeling" and "Numerical Simulation" are 2 closely related, self-explanatory topics; but "Applications" puzzled me at first; however, it proved to be as good a word as any to encompass the topics of chest-wall-vibration therapy, a calculated lung status index, and proportional-assist ventilation. The text's common denominator is its biomedical engineering view of, primarily, the ventilation and gas-exchange functions of the pulmonary system.

The editor states that the book is the "result of a 10-year research collaboration." I hoped that this would lead to strong cohesion between the chapters, with one topic following neatly to the next. The existence of a glossary in the front matter strengthened my hope for a tightly knit work. It surprised me, then, that the chapters are such a diverse grouping. Several chapters are the work of the editor and several coauthors, and thus have similar topics and a similar feel. Otherwise, the chapters are as disparate in their subject matter as they are in their readability.

In addition to the topics listed above, this book includes chapters about respiratory gas diffusion through a spatial network of red blood cells, mechanical models of lung ventilation, airflow in a particulate-doped lung, and a toxicity index for inhaled neurotoxins. Some of these analytical models are relatively simple (eg, the model that represents the lungs as a resistance-compliance electrical network). Other models, such as the finite element representation of the airway tree, are extremely complex, both mathematically and computationally. It is doubtful that anyone will be familiar with all the techniques introduced in this volume. The book has value in making the reader aware of various ways that biomedical engineering can be applied to the respiratory system.

Returning to the glossary, I would have been extremely impressed if the editor had convinced his fellow authors to adhere to a single set of abbreviations. Engineers and physicists are notorious for choosing their own particular symbols and sticking to them. I thought the glossary looked too short to include the terms from all 10 chapters, and the first chapter proved me correct. The glossary incompleteness is a slight annoyance, as most of the authors have taken care to define their terms, and they often use abbreviations that are common in pulmonary research. There is the odd symbol that creeps in every now and then. One that stands out, and appears in several chapters, is the use of a V with an open circle (instead of a dot) above it to denote ventilatory flow. While this does not hinder understanding, it is unorthodox.

The first chapter opens with a remarkably concise yet thorough review of anatomy and physiology by Johnson and Hsia. To give you an idea of the brevity, adult anatomy is dispatched with 2 short paragraphs and the standard Weibel airway-generation schematic. This chapter is also the first hint of the physics bent of this book. The authors discuss 2 dimensionless flow and transport parameters: the Reynolds and Péclet numbers. The treatment of laminar versus turbulent flow, as represented by the Reynolds number, can be found in many graduate level pulmonary physiology texts. However, before reading this chapter I had not seen the parallel analysis using the Péclet number to estimate relative convection and diffusion of the respiratory gases. The reader needs to be familiar with similar concepts to understand the topics presented. I nevertheless enjoyed seeing the engineering treatment of pulmonary physiology from the onset of this volume.

The editor, Kulish, offers this compilation as recent advancements in pulmonary bioengineering for researchers and students. I found it hard to judge the merits of this claim. Some of the work, with which I am familiar, is currently ongoing. Other projects, judging from their citations, appear to have been dormant for a number of years. A case in point is Lua and Shi's chapter, "Mechanics of Proportional Assist Ventilation." This ventilator design has 2 separate settings, one for flow and the other for lung volume, used to adjust the gain to amplify a patient's inspiratory effort. I polled several pulmonologists I work with before finding one familiar with this ventilator. He informed me that proportional-assist ventilation units are found in Europe, but are not used in the United States. The most recent citations in this chapter that deal directly with proportional-assist ventilation are nearly 10 years old. This makes me question whether this topic can be considered a recent advancement and whether there is any current engineering moving the technology forward. Even though the research about this topic may be a little stale, the authors' description of this ventilator intrigued me enough to do some outside reading on the topic.

The chapters are of extremely uneven quality. On the lower end is the chapter about "Lung-Gas Composition and Transfer Analysis," by Ghista et al, who were inconsistent with the values they chose to represent expired gas composition. These discrepancies are trivial but should have been corrected, because they confuse the reader. The writing style of this chapter is poor; it is not much more than equations separated by single phrases or sentences. After plodding my way through the derivations, I had that lost feeling that comes from skipping class for a week and trying to catch up with a classmate's notes. The authors attempt to describe the concentrations of oxygen and carbon dioxide in inspired and expired air and derive a method for determining gas-diffusion rates with respect to cardiac output. The calculated diffusion coefficients can then be used as indices of lung performance. Other than a case study, the authors do not attempt to show clinical sensitivity or specificity for the calculated diffusion coefficients. I am unclear as to the utility of this method in a clinical setting.

Tawhai's chapter "Anatomically Based Modeling of Pulmonary Structure" sits in stark contrast to the one described above. The mathematics needed to describe the formation of a mathematical airway tree could easily overwhelm the reader. Tawhai here opted for a prose description that I found informative and easy to read. Clear graphics supplement the text; for example, one figure shows how a standard airway tree morphs to an individual representation based on computed tomography scans. I felt that I came away from this chapter with a fair understanding of the methods involved. The ultimate aim of this research is to produce a patient's individualized computational model of the pulmonary system, from the trachea down to the alveoli and capillary networks.

The quality of the graphics is one place where this book shines, when compared to its siblings. The quality varies somewhat between chapters, but most chapters have clean, crisp line plots and graphs. There are only a few bitmapped images; even these pixilated plots are legible. This is a welcome change from many previous texts of this type.

Many of the chapters could have used some editing to correct overlooked points in the methods, spelling, and other minor errors. Units, especially, are an issue throughout. Pulmonary resistance and compliance units are variously contorted into both correct and incorrect versions, sometimes switching within a single chapter. This is one place where the editor should have imposed consistency. In a chapter authored by the editor, several plots refer to incorrect equation numbers, making it awkward to follow his results. These errors are inconsequential.

However, I take issue with the calculation of work of breathing in the chapter "Lung Ventilation and Modeling Assessment," by Ghista et al. Pressure-volume work is the integral of pressure with respect to volume ($\int PdV$), and not the integral of volume with respect to pressure ($\int VdP$). The calculations in this chapter are valid only because they take into account an entire breath, which is the only time these 2 formulations agree. The mistakes throughout the text add to the feeling that some of the authors did not give appropriate attention to their final product.

I began reading this book hoping that it would expose me to fresh ideas in mathematical modeling of the respiratory system. I was rewarded most notably by the 3 "Applications" chapters, primarily because I had no previous familiarity with these topics. Overall, the majority of the chapters are well developed and presented clearly and thoroughly. However, several topics disappointed me, especially when the authors did not convince me that their research has any application outside of this text. Better editing to strengthen the weaker chapters would have mitigated my hesitancy to recommend this compilation.

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