Preface

Medicine is a fascinating field whose progress has been exponentially accelerated from the moment it met technology. Mathematics, along with physics and chemistry, participates in such an exciting experience, which actually started long ago.[1]

In the present book we focused our attention on one of the most intriguing branches of medicine: hematology. Blood has an extremely complex behavior at all scales. It is complicated as a fluid (to the point that many different, often mutually contrasting, rheological models have been proposed), it contains very smart cells, able to perform a huge number of operations, and it carries a great number of large and small molecules, each with one or more tasks. Moreover, it constantly interacts with all organs providing oxygen and nutrients, exchanging gases in the lungs, carrying throughout the body hormones synthesized by endocrine glands, and cells defending the organism from the attack of foreign agents. Blood also takes metabolites to their final destination (the kidneys).

Such a monumental physiology goes in parallel with an even more intricate pathology, since there are so many different ways of perturbing a system which works perfectly in a rather narrow range. In this framework mathematics can play an important role. In which way? It is not so simple to describe some general rule for the construction of a mathematical model. It is not just a matter of choosing the appropriate equations. Putting together a number of appropriate equations could lead to a system which is simply not manageable. Moreover equations contain coefficients and if the model has to give practical answers, then such coefficients must be known from experiments. Therefore quite often completeness is in conflict with practice. The more difficult are the phenomena to be studied, the more necessary is to simplify equations, and simplifications always need to be justified and kept within a tolerance degree guaranteeing that the reduced model is still meaningful, at least for some specific target.

[1] See the recent book: F.A. Duck. Physicists and Physicians: A History of Medical Physics from the Renaissance to Röntgen. Institute of Physics and Engineering in Medicine, 2013.

Blood-related topics are so numerous and each subject has been so widely studied that it would be unthinkable to write an encyclopedic book. We will just deal with some aspects of particular importance, showing old and new approaches of mathematicians. We found extremely interesting, and also quite amusing, to examine the historical development of the branches of medicine we dealt with. Of course in a very synthetic way. Sometimes old ideas may look ridiculous, and we confess that here and there we have played around the striking contrast between old and new, emphasizing the naivety of our ancestors. Nevertheless, we want to stress that the old civilizations and their masters were facing a task which was extremely arduous and that even mistakes of great minds may have contributed in a way to the progress of science. If on the contrary they have been an obstacle to the path towards truth those who have to be blamed are not Hippocrates, Aristotle, Galen, and the other fathers of medicine, but the strenuous vacuity of their followers. On the other hand, when we "ultrafiltrate" history (to anticipate a term we will extensively use in the chapters on kidneys and dialysis) the view emerging from such a compressed perspective is so distorted that we should abstain from hastily judging those who have mistakenly opposed the genial ideas mining their obsolete world. Obstinate blindness is nothing but the natural and often justifiable instinct of preserving the cultural environment we are born in, which pushes us to react negatively to what may look the arrogant extravagance of self-appointed innovators. Indeed, in sciences as in the arts, among the crowd of those proposing new ideas, very few are really able to change the course of history, because this requires an exceptional mind and the exceptional bravery of taking on seemingly impossible challenges. We will encounter some of these towering characters on our path and we will try to communicate our personal admiration, so that the reader does not get the impression of being just looking at tombstones, but can somehow imagine the excitement of the great people who made medicine what is today.

Due to its interdisciplinary character, the book is addressed to a large audience. To clinicians, with the hope of elucidating the practical importance of mathematics in medicine, to mathematicians with a taste for applications, but also to all scientists (engineers, biologists, technicians, etc.) working in or close to medical areas. In addition, even people with no scientific background can enjoy at least the pages dedicated to the history of the relevant branches of medicine and the biological introductions to the various subjects. A last remark is about footnotes. There are many. In a sense they make a parallel book, containing a lot of lateral thoughts and pieces of information, frequently of historical character, which in our opinion provide answers to questions that may arise naturally.

The book deals with several specific aspects: blood rheology, blood coagulation, blood ultrafiltration (natural and artificial), gas exchanges, the role of blood in heat transfer, blood generation, and leukemia. All chapters follow the scheme: historical background, physiological basis (including pathologies), mathematical modeling. The subject of ultrafiltration is divided in two chapters: one small (kidneys) and, one large (hemodialysis) for the reason that the two processes are significantly different. The literature on kidney modeling is not large and we illustrated our own approach to the problem, resulting from the applications of concepts on microcirculation

illustrated in the first chapter. This explains why it is much shorter than all other chapters. Nevertheless we kept it separate because of its absolute peculiarity.

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