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Preface

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This special issue entitled *Direct and inverse modeling of the cardiovascular and respiratory systems* is by no means an attempt at comprehensively representing the global state of the art in the field, far too wide to be encompassed in a single volume – even when specializing it to applied mathematics approaches. Nevertheless, it very nicely reflects an attractive diversity and a strong momentum around the proposed topics.

Some interesting evolution trends can be observed in this collection of papers, which we believe are quite representative of the wider context in this field. The first is that applied mathematicians do not hesitate to directly address – and often initiate, indeed – *novel modeling* endeavors. Namely, mathematicians do not restrict themselves to the analysis of earlier proposed modeling equations, and to the numerical analysis required to formulate effective solution procedures thereof, which of course remain very important objectives *per se*. This probably has to do with the "pioneering spirit" prevailing in this rather young field, with the impetus induced by tremendous modeling needs. Together with the scarcity of pre-established modeling communities, this certainly encourages mathematicians to directly set foot in modeling issues . . . and discover that they are often rather well-equipped to propose sound modeling equations with suitable corresponding numerical strategies. The second clearly-identifiable trend is that *inverse problems* – in a wide sense including, of course, estimation and data assimilation, but also control and optimization – are essential in this field. In our minds, this relates to the very nature of the objects of concern, namely, *living systems*, of which pre-existing knowledge (of e.g. detailed constitutive parameters, or even initial conditions in dynamical behavior) is intrinsically limited due to inter-individual variability, the effects of pathological conditions, etc., whereas "invasiveness" concerns naturally restrict extensive experimental determination. Nevertheless, a wealth of measurements (signals, images, and so on) is generally available for such systems, which raises important and challenging inverse problems of various types.

Accordingly, the contributions can be roughly divided into two groups, the first one dealing with the direct modeling of the respiratory and cardiovascular systems, and the other one with optimal control and inverse problems associated with these topics.

Models of the cardiovascular and respiratory system are multiphysics by nature. For example, poro-mechanics, electro-mechanics or fluid-structure interaction have been the topics of many publications during the past decade. In this spirit, the article by Martin and Maury addresses the transfer of oxygen into the blood coupled with a mechanical respiratory model. Cardiovascular and respiratory models – like in all living systems – also frequently involve multiscale phenomena that cannot all be treated with the same level of detail. In the contribution by Watanabe, Blanco and Feijóo, a complex network of one-dimensional models and its interaction with a three-dimensional compartment are considered for an extremely refined description of the hemodynamics in the arm. In the work by Rioux and Bourgault – concerned with cardiac electrophysiology – the reduction of complexity is achieved by considering a phenomenological model of cell membranes, which is shown by means of a mathematical analysis to be well-suited to parameter calibration based on typically available data. Of course, complexity is also a major concern in numerical computations. For example, the models commonly

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used in cardiac electrophysiology are known to be extremely demanding in computational resources. Effective iterative methods and preconditioning are therefore of utmost importance in this field. This is the topic of the contribution by Colli Franzone, Pavarino and Scacchi, who propose and analyze a new procedure to solve the bidomain equations, by iteratively solving two scalar subproblems.

As in any other field of science and engineering, bioengineering models must be parametrized in order to be adapted to specific situations. Stimulated by the constant progress in medical data acquisition – in particular medical imaging – data assimilation methods and inverse problems have attracted a growing interest in last few years. In this context, d'Elia and Veneziani investigate a Bayesian approach to quantify the uncertainties in the velocity field measured in blood vessels. Another inverse problem specific to the *in vivo* observations of artery walls is the estimation of internal stresses, or conversely the identification of a stress-free configuration. This question, which has been studied in various publications in the recent years, is addressed with a new algorithm by Bols, Degroote, Trachet, Verhegghe, Segers and Vierendeels.

The ultimate goal in modeling and simulation is often to optimize or control a system. The contributions of Kunisch and Wagner, on the one hand, and of Lassila, Manzoni, Quarteroni and Rozza on the other hand, address this type of challenge, in electrophysiology and in hemodynamics, respectively.

The combination of these new modeling approaches, computational techniques, parameter estimation and sensitivity methods, and optimization and control strategies can ultimately lead to new developments in the life sciences, and indeed medical diagnosis and intervention.

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