Preface

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In the year 2000 a series of papers on ‘Cardiovascular Soft Tissue Mechanics’ was published in a special issue of the Journal of Elasticity, with guest editors Stephen C. Cowin and Jay D. Humphrey. This compilation of seven papers has been very successful and very influential in the further development of the mechanics of fibrous tissues (over 2,000 citations as in May 2017, according to the Web of Science). Since 2000 there has been much progress in the modeling and simulation of soft tissue mechanics and it is now considered an appropriate time to produce a further special issue, but now focusing on broader aspects of soft tissue mechanics. We have therefore brought together a collection of 12 papers from selected leading experts in the field to provide particular reference to multiscale modeling and mechanobiology for a range of different soft tissues, such as arteries, the eye, the brain, and the heart.

Of particular importance these days is the development of multiscale models that are able to link two or more length, time or energy scales to inform the macroscopic response of tissues. This needs advances not only from the constitutive modeling point of view but also from the computational perspective because the transition from the nano- to the micro- to the macro-level is a key aspect which needs further development. Mechanobiology is concerned with studies of the cellular biological responses due to changes in the mechanical environment and has gained significant importance in the last 15 years, in particular in relation to soft biological tissues. Indeed, the word ‘mechanobiology’ was not mentioned in any of the papers in the 2000 special issue. Hence, modeling in mechanobiology has much promise for the future understanding of mechanical and biological interactions.

We now briefly describe the contents of each of the papers in this issue. The paper by Lanir [1] provides an extensive review of the characteristic features of soft tissue structures

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and their constitutive modeling. It includes a brief survey of the multiscale and multiphase soft tissue structure and the mechanical characteristics of both soft tissues and their constituents. Using structure-function relationships, the means by which tissue structure remodels during growth in order to adapt to physiological function is discussed. As a particular example of multiscale modeling the paper by Holzapfel and Ogden [2] reviews fiber dispersion models that are used for capturing the biomechanical response of fibrous tissues with particular reference to excluding compressed fibers within the models. The analysis suggests that the predictive powers of the general structure tensor and the angular integration models are very similar, contrary to some claims in the literature.

The next few papers deal with different aspects of growth for various tissues. The article by Nims and Ateshian [3] provides several examples to illustrate an approach to modeling the solid matrix of biological tissues using reactive constrained mixtures including chemical kinetics. Exchange of mass between various constituents of a mixture is used to describe tissue growth and remodeling. The next two papers by Ambrosi *et al.* [4] and Rausch and Humphrey [5] describe multiscale models of biological, chemical, and mechanical contributions to growth. The first is an application to solid tumors treated as poroelastic solids, while the second one concerns an application to the growth and remodeling of a thrombus. The following two papers by Pinsky and Cheng [6] and Grytz and El Hamdaoui [7] focus on computational models of the eye, lens-induced myopia and the cornea. Pinsky and Cheng [6] develop a constitutive model which accounts for the swelling pressure in hydrated connective tissue with particular reference to swelling in the human cornea, and the model predictions were found to be in good agreement with experimental data. Grytz and El Hamdaoui [7] develop a mechanical model for the sclera in which growth and remodeling were considered to be independently controlled mechanisms during eye development. This model was also found to be in agreement with experimental data.

The next three papers are related to modeling brain bulging, buckling of layers of grey and white matter and axonal buckling in the brain. In particular, the paper by Weickenmeier *et al.* [8] models the swelling-induced deformation in bulging brains. The proposed approach has the potential to inform surgeons of possible ways to reduce brain damage and to improve the outcomes of the procedure of decompressive craniectomy. The study by Ben Amar and Bordner [9] proposes a simple model of growth for a bilayer of grey and white matter using a neo-Hookean model in the short and large wavelength limits. By a post-buckling analysis the gyrification index is predicted and compared with experimental data. Lang *et al.* [10] test the hypothesis that localized stretching is a possible explanation for the regional buckling of axons modeled as Euler beams on an elastic foundation, where the elastic foundation models the surrounding brain tissue. The solutions of the model are consistent with experimental observations of the undulations induced in stretched axons.

The last two papers of this special issue are related to growth and remodeling of cardiac tissue. The study by Witzenburg and Holmes [11] examines eight constitutive laws and compares their relative predictions on the basis of a simple one-dimensional test-bed. Wang *et al.* [12] summarize recent state-of-the-art modeling studies of cardiac growth and remodeling in health and disease, and use a finite element approach to simulate growth in an embryonic linear heart tube with the aim of better understanding the role of structural remodeling in heart failure.

In multiscale modeling and mechanobiology much progress has clearly been made in the last few years, but these subjects are still in their infancy and require much more development. In particular, much more detailed experimental data are needed at the nano- and macro-levels in order to inform the modeling and to better understand the underlying mechanisms. Moreover, improvements are needed in the mathematical and computational meth-

ods for upscaling from the nano- through to the macro-scale. We hope that this special issue provides some stimulus to the scientific community to help the further development of these exciting subjects.

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