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MODELING, SIMULATIONS, AND EXPERIMENTS TO STUDY OCULAR FLUID MECHANICS, BIOMECHANICS, AND DRUG DELIVERY

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ABSTRACT

Alterations in the eye can often serve as early indicators for various vascular and systemic diseases, preceding their manifestation in the rest of the body [1]. In the eye, hydrodynamic and biomechanical changes can be visualized and measured non-invasively in vivo. Mathematical, computational, and statistical modelling, used in synergy with clinical and experimental data, can thus be profitably used to identify possible driving mechanisms, isolate important biological factors, and test clinical hypotheses [2].

A broad spectrum of mathematical approaches is employed, including data-driven modelling, uncertainty quantification, fluid-structure interaction methods, free-surface modelling, and compartmental models. In addition, recent advances in hybrid modelling strategies, combining mechanistic and data-driven approaches, open new avenues for the development of patient-specific simulations and real-time predictive tools. Digital twin frameworks are particularly promising in this context, enabling adaptive and interpretable models that integrate multiscale data, from tissue-level mechanics to drug transport and metabolism.

This minisymposium aims to investigate different regions and functions of the eye, which include, proceeding from its exterior to the interior: tear film fluid mechanics, biomechanical corneal properties and contact lens interactions, and the biochemical, electrical, thermal, and

vascular components of drug delivery. We encourage contributions that explore coupling between scales and physics, surrogate modelling to reduce computational costs, and data assimilation techniques for integrating sparse or noisy measurements. Of particular interest are works that combine theoretical and numerical approaches with experimental validation, and that provide insights into personalized modelling of ocular systems. By focusing on both biological relevance and methodological innovation, this minisymposium seeks to foster interdisciplinary exchange among mathematicians, engineers, biophysicists, and clinicians working toward the modelling and simulation of the eye as a complex, dynamic, and diagnostically informative system.

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