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Magneto-mechanics meets biology: experiments, modelling and future perspectives

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Abstract

Understanding how mechanical forces regulate biological function requires tools that can reproduce the complex, time-dependent and heterogeneous mechanical environments experienced by cells and tissues [1,2]. In this talk, we will present a unified framework that bridges magneto-mechanics, materials engineering and mechanobiology, built upon a new class of ultra-soft magneto-active polymers specifically designed to interface with living systems [3]. First, we will discuss the experimental foundations of these materials, highlighting how controlled magnetic actuation enables the generation of programmable multi-axial deformations, stiffness gradients and dynamic mechanical cues in vitro [3,4]. These capabilities allow us to replicate physiologically relevant conditions that are inaccessible with traditional mechanobiology platforms. Second, we will introduce our multiscale modelling strategy, which couples constitutive magneto-mechanical formulations with finite element simulations and data-driven inverse models [4-6]. This hybrid approach allows us to predict deformation fields, guide material design and rationally engineer mechanical microenvironments for biological studies. Finally, we will present current and emerging applications, ranging from the characterization of tissue-like materials to the mechanical modulation of cell behaviour, tumour progression and neural mechanotransduction [3]. We will conclude by outlining our future perspectives on magneto-mechanics as a powerful enabling technology for the next generation of experimental models and therapeutic strategies in mechanomedicine. References: [1] D. Garcia-Gonzalez. Magneto-mechanics in mechanobiology: enabling remote force transmission to cells and extracellular matrix. Biophysical Reviews, 2025,

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