ME Seminar

Multi-scale mechanics of soft tissues: adaptation across scales and time

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ABSTRACT

The mechanical behaviour of biological tissue emerges from coupled interactions spanning multiple length scales. Tissues such as skeletal muscles, for instance, generate forces through active and passive hierarchical interactions between cellular and tissue scales, which adapt as they age. Similarly, during brain development, micro-scale processes such as cell proliferation and migration affect the evolving mechanical environment, forcing it to continuously adapt through growth and remodelling. Understanding how small-scale changes in material properties, geometry, and loading propagate upward to alter macroscopic tissue function remains a challenge.

To address these challenges, in this talk, I will present computational approaches for modelling soft tissues as multi-scale systems, using the finite element method as the numerical foundation. In the context of skeletal muscle, a homogenization-localization scheme is used to investigate how meso-scale constituents (muscle fibres and extracellular matrix) govern macro-scale deformation and force transmission. However, soft tissues not only transmit forces, but also grow and remodel in response to their mechanical environment. Using the theory of finite growth, the effect of tensile stresses generated during cortical folding in the developing brain will be discussed, demonstrating the role of mechanics in tissue morphogenesis. Building on these works, I will discuss my future research on coupled multi-physics models of muscle adaptation, focused on simulating tissue remodelling in diseases such as sarcopenia. By linking continuum mechanics with biologically informed remodelling, this work aims to provide predictive tools for understanding muscle function in aging and disease, with applications in rehabilitation and intervention design.

ABOUT THE SPEAKER

Dr. Karan Taneja is a computational biomechanist, specializing in using multi-scale methods and physics-informed machine learning to simulate multiple biological tissues. Collaborating with clinicians and experimentalists, he aims to understand how micro-structural changes affect macro-level behaviors in soft tissues, providing insights that can help comprehend their role in related pathologies. He worked as a postdoctoral researcher at the University of Notre Dame, where he developed models for cortical folding and validated growth-based simulations with histological data. He earned his Ph.D. (structural engineering) from University of California San Diego (2023), M.Sc.(structural engineering) from TU Delft (2017), and B.Tech (civil engineering) from Delhi Technological University (2013). Currently, he works as an R&D engineer at Ansys (part of Synopsys), leveraging his expertise in modelling multi-scale systems and the use of biomedical imaging to enhance their multi-physics solver capabilities.

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