Multiscale modeling reveals the role of microscale in the biomechanics of soft tissues

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Biological tissues exhibit a distinctive interplay between structure and function, which is crucial for understanding their mechanical behavior. The intricate organization of cells and protein networks, coupled with their capacity to adapt to external stimuli or internal changes, governs the mechanobiology of tissues in both health and disease. Microstructure-informed computational models are developed as powerful tools to elucidate this relationship, linking microscopic features to macroscopic mechanical responses. Particularly, multiscale models based on Representative Volume Elements (RVEs) explicitly incorporate microstructural architecture and mechanical properties of invidual constituents, offering insights into local kinematics and how this influences the macroscale behavior.

This talk presents a general framework for multiscale modeling, employing numerical homogenization of RVEs paired with multiscale boundary conditions. A one-dimensional random fiber network is integrated within a three-dimensional finite element mesh using the technique of embedded elements, which ensures superior computational efficiency [1]. Two applications in soft tissue biomechanics illustrate the model's utility. In a first example, a two-scale finite element model of an aortic aneurysm captures altered collagen fiber kinematics during disease progression [2]. In the second application, a microscale model of human brain white matter with a random wavy network of neuronal axons is developed, based on histology-derived distributions. An inverse parameter identification scheme is proposed to obtain the mechanical parameters of the microstructural constitutents [3].

References

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