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INTEGRATIVE COMPUTATIONAL AND EXPERIMENTAL APPROACHES FOR MODELING BIOLOGICAL SYSTEMS

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ABSTRACT

The increasing availability of experimental, imaging, clinical, and population-level data, together with rapid advances in computational science, is creating new opportunities for quantitative modeling of complex biological systems. However, biological problems are inherently multiscale, nonlinear, heterogeneous, and data-limited, making it difficult for any single experimental or computational method to fully describe system behavior. Integrative approaches that combine experiments, mechanistic models, data-driven methods, and advanced computational techniques offer a promising path toward more predictive and interpretable models.

This invited session will bring together researchers developing and applying integrative methodologies for modeling biological systems. Particular emphasis will be placed on approaches that connect experimental measurements, mathematical and computational models, and heterogeneous sources of biological and biomedical data.

Topics will include computational mechanics; experimental–computational integration; physics-based and data-driven modeling; scientific machine learning; reduced-order and surrogate modeling; multiscale and multiphysics methods; parameter estimation and inverse problems; uncertainty quantification; image-based modeling; model calibration and validation; and strategies for integrating sparse or heterogeneous datasets. Applications may span tissues, organs, physiological systems, medical technologies, and other complex biological systems.

A central objective of the session is to foster interactions among researchers who traditionally approach biological problems from different perspectives, including applied mathematics, computational science, biomechanics, engineering, data science, and experimental research. The session will highlight how complementary methodologies can be integrated to overcome limitations in individual approaches and enable models that are computationally efficient, experimentally informed, and capable of addressing complex biological questions. Particular attention will be given to emerging methodologies that facilitate translation from fundamental mathematical and computational developments to biomedical and technological applications.

IS Topics: Computational modeling; experimental–computational integration; scientific machine learning; physics-informed modeling; reduced-order modeling; surrogate modeling; multiscale and multiphysics methods; inverse problems; uncertainty quantification; image-based modeling; biomechanics; biomedical applications.