

Digital Twins for Biological Systems: Advancing Multiscale Modeling and Hybrid Solutions

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Digital twins (DTs) rapidly emerge as transformative tools for understanding and controlling biological systems, from microbial communities to human physiology. By integrating mechanistic models with data-driven approaches, these frameworks enable predictive and adaptive simulations, offering new avenues for biomedical research, personalized medicine, and bioprocess optimization. However, modeling biological systems presents unique challenges, including multiscale dynamics, complex metabolic and physical interactions, and the need for robust, interpretable, and computationally efficient solutions.

This mini-symposium will explore advances in multiscale modeling, hybrid solver strategies, and data assimilation techniques for DTs in biology. Topics will include coupling multiscale dynamics through ODEs and PDEs, integrating physics-based and data-driven methods to enhance predictive accuracy, and optimizing computational performance using model reduction techniques (*e.g.*, surrogate models). By gathering experts in mathematical modeling, numerical analysis, and data assimilation, this mini-symposium aims to foster interdisciplinary collaborations that advance the development of scalable, interpretable, and validated DTs. The session will highlight applications across various domains - from microbial ecosystems and bioengineering to clinical diagnostics and treatment optimization - emphasizing methodological innovations and real-world impact.

Confirmed invited speakers :

- 1. Eleonora Pastremoli (MaIAGE, INRAE) Towards a Digital Twin of the Gut Microbiota : Multiscale Modeling and Host Interaction;
- 2. Sthyve-Junior Tatho-Djeanou (PLEIADE, INRIA) Community metabolic flux analysis (cMFA) for multi-omics data integration in microbial community models;
- 3. Alexis Valls (MEMPHIS, INRIA) Real-time turbulent flow estimation through data assimilation and stochastic closure of reduced order models;
- 4. Thomas Saigre (Université de Strasbourg) Combining Physics-Based Modeling and Data Analytics Methods To Develop a Digital Twin for Ocular Applications;
- 5. Agustin Yabo (MISTEA, INRAE) Understanding, modeling and controlling wine fermentation.