Microbes-Mechanics-Materials: A Critical Nexus Awaiting Exploration

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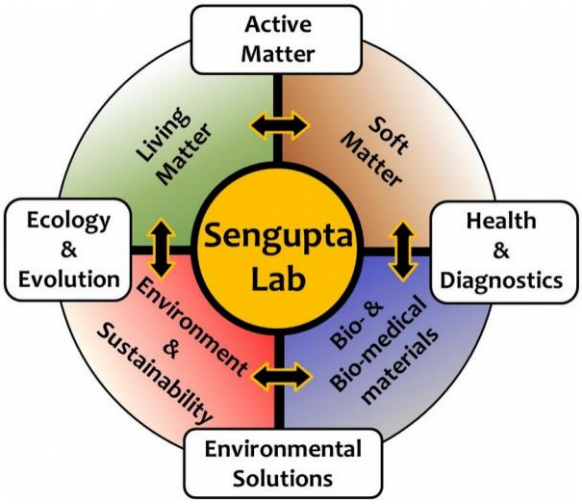
Understanding how microbes interface, exchange and communicate with their local surroundings is central to the grand quest for a theory of microbial ecology. From simple to complex fluids, from compliant to rigid environments, microbes inhabit plethora of dynamic settings spanning vastly different structures, internal energies, and interacting cues. Currently we lack a biophysical framework that could explain, generalize, and crucially, predict the *if-s*, the *how-s*, and the *why-s* of the microbe-environment feedbacks. Research in my lab aims to fill this gap by interfacing soft and active matter physics with microbiology and genetic engineering, often with generous support of 3D microfabrication, automation, quantitative imaging and machine learning tools. Using vignettes from our recent works in model gut and aquatic microbial systems, I will present the critical role of phenotypic noise–both intrinsic and imposed–in establishing biomechanical coupling between microbes and their micro-environments, and demonstrate how this ultimately leads to emergence of biophysical traits which govern ecological and eco-physiological functions. I will discuss the generality of our results across microbial populations and taxa, specifically touching upon the smart and active architecture associated with such dynamic microbial ensembles, and the emergent transport processes which enable information cascades at collective scales. I will conclude by showcasing recent efforts of my team to leverage the *mi-me-ma* nexus in understanding the ecology of microbes associated with specific cancer types, and more broadly, to harness the biophysical feedbacks for designing bioremediation, medical diagnostic and biotechnology applications.



About the Author

Anupam Sengupta is an FNR-ATTRACT Fellow and a professor of biophysics at the University of Luxembourg. He holds Bachelor and Master degrees in Mechanical Engineering from the Indian Institute of Technology, Bombay (India). After a short stint in industry, Anupam joined the Max Planck Institute for Dynamics and Self-Organization, Göttingen (Germany), where he received a Ph.D. in condensed matter physics in 2013 for his work on liquid crystal microfluidics. Between

2014 and 2017, Anupam was a Human Frontier Cross-Disciplinary Fellow, first at the Massachusetts Institute of Technology (USA) and then at the ETH Zurich (Switzerland), working on a range of problems on the physical ecology of microorganisms, with an overarching question of microbial adaptation under changing climatic and biomedical scenarios. Since 2018, Anupam is based in Luxembourg where he heads the Physics of Living Matter Group. The multi-disciplinary Sengupta Lab combines material physics, microbiology, mathematical modelling and machine learning to understand microbial response and adaptation to different dynamic settings, from marine and fresh water ecosystems to the human gut and cancer environments. Currently, Anupam is a member of the Institute of Advanced Studies at the University of Luxembourg, and among other roles, serves as the Director of the Physics Studies of University of Luxembourg.