SYGF 1: Guest Country Symposium France: Soft, Active and Alive: Emergent Properties in Living Matter (SYGF)

Time: Wednesday 15:00–18:15 Location: HSZ/AUDI

Invited Talk SYGF 1.1 Wed 15:00 HSZ/AUDI
Liquid crystal geometries in type I collagen-based tissues — •Nadine Nassif — Sorbonne Université/CNRS, UMR7574, Paris, France

Many biological tissues exhibit hierarchical fibrillar architectures that resemble the geometry of liquid crystalline phases. Such ordering occurs in matrices composed of collagen, chitin, cellulose, or DNA, and governs essential structure/property relationships. Bone and cornea are two emblematic examples: bone exhibits a twisted-plywood architecture, whereas the cornea displays a highly organized orthogonal plywood arrangement that ensures transparency and mechanical integrity. In bone, collagen confinement creates supersaturation of proteins and ions, with major consequences for mineral formation. Our research aims to reproduce the collagen-based building blocks underlying these tissues to better understand morphogenesis and develop advanced biomaterials. Type I collagen shows lyotropic behavior, forming successive ordered phases and retaining liquid-crystal organization during fibrillogenesis. Using a bioinspired continuous-injection process mimicking cellular secretion, we scale up collagen assemblies from droplets to 3D bulk materials. Their biomimetic mineralization produces collagen/apatite composites with strong structural and functional similarity to bone, as demonstrated by in vitro and in vivo investigations. Overall, our results demonstrate the importance of physico-chemical processes in biomineralization, which are usually discussed from a biological perspective.

Invited Talk SYGF 1.2 Wed 15:30 HSZ/AUDI
Self-organization of the cytoplasm by physical instabilities — •Jan Brugues — Cluster of Excellence Physics of Life, TU-Dresden, Dresden, Germany

Early development across vertebrates and insects critically relies on robustly reorganizing the cytoplasm of fertilized eggs into individualized cells. This intricate process is orchestrated by large microtubule structures that traverse the embryo, partitioning the cytoplasm into physically distinct and stable compartments. Despite the robustness of embryonic development, here we uncover an intrinsic instability in cytoplasmic partitioning driven by the microtubule cytoskeleton. We reveal that embryos circumvent this instability through two distinct mechanisms: either by matching the cell cycle duration to the time needed for the instability to unfold or by limiting microtubule nucleation. These regulatory mechanisms give rise to two possible strategies to fill the cytoplasm, which we experimentally demonstrate in vitro and in zebrafish and Drosophila embryos. Our results indicate that the temporal control of microtubule dynamics could have driven the evolutionary emergence of species-specific mechanisms for effective cytoplasmic organization. Furthermore, our study unveils a fundamental synergy between physical instabilities and biological clocks, uncovering universal strategies for rapid, robust, and efficient spatial ordering in biological systems.

Invited Talk SYGF 1.3 Wed 16:00 HSZ/AUDI
From morphogenesis to space partitioning by microtubules and molecular motors. — •Manuel Thery — ESPCI, Paris, France

Microtubules are not just tracks for transport; they can also be moved by the forces exerted by molecular motors. In this presentation, we will first demonstrate how the interplay between moving microtubules and transported motors can result in the emergence of shapes from random mixtures (morphogenesis). We will explain how these shapes are maintained in dynamic steady-states by active and polar boundaries. Then, we will explore the plasticity and adaptation of these boundaries to geometric constraints, as well as their ability to polarise or bipolarise a confined space (space partitioning). Finally, we will discuss the relevance of this process to various forms of intracellular organisation.

15 min. break

Invited Talk SYGF 1.4 Wed 16:45 HSZ/AUDI
More than the sum: how composite interfaces govern function — •Alba Diz-Muñoz — European Molecular Biology Laboratory, Heidelberg, Germany

The cell surface of animal cells is a composite interface with several layers, the plasma membrane, the actomyosin cortex and a membrane-to-cortex attachment protein layer that binds them together. Biochemically and mechanically each of these layers differs. My group is taking an engineering-inspired approach, combined with traditional cell biology methods, to quantitatively measure and predict how the various mechanical layers at the surface of animal cells govern function. Together, our work identifies membrane-to-cortex attachment as a critical mechanotransducer in cells, and the membrane-to-cortex distance as a key geometrical parameter that regulates protein activity at the cell surface.

Invited Talk SYGF 1.5 Wed 17:15 HSZ/AUDI
Swimming and Swarming of Intelligent Active Particles — Segun Goh[1,2], Priyanka Iyer[1], Rajendra Singh Negi[1], and •Gerhard Gompper[1] — [1]Institute for Advanced Simulation, Forschungszentrum Juelich, Germany — [2]Sejong University, Seoul, South Korea

The collective behavior of motile active matter displays many emergent self-organization, like flocking and swarming [1]. For living systems, as well as microrobotic systems, activity and locomotion is combined with sensing of the environment and adaption of motion. We study such system by considering models of ‘intelligent’ active particles with visual perception and self-steering in both dry [2,3] and wet systems [4,5].

Here, we focus on wet systems, where hydrodynamic interactions contribute significantly or dominate the self-organization [4,5]. Pusher- and puller-type squirmers display very different emergent behaviors. Pusher-pursuers may not be able to catch up with pusher-targets even at larger pursuer speeds [4]. Also, aligning pushers can form stable pairs only with speed adjustment of the pursuer . In large ensembles, pushers display active turbulence, while pullers form unstable clusters, vortices, and jets [5].

[1] G. Gompper et al.; J. Phys. Condens. Matter 37, 143501 (2025). [2] R.S. Negi et al.; Phys. Rev. Research 6, 013118 (2024) [3] P. Iyer et al.; Commun. Phys. 7, 379 (2024) [4] S. Goh et al.; Commun. Phys. 6, 31 (2023) [5] S. Goh et al.; Phys. Rev. Research 7, 013142 (2025)

Invited Talk SYGF 1.6 Wed 17:45 HSZ/AUDI
Perturbing the collective motion of fish with challenging environments — •Aurélie Dupont — LIPhy, CNRS Univ. Grenoble Alpes, Grenoble France

Collective movements can be observed across species and on various scales: from bacteria to mammals. We are interested in the collective behavior of small fish when confronted with external physical perturbations. When forced to escape through a narrow opening, most animals behave like granular materials and clogging events decrease the efficiency of evacuation. In this emergency exit scenario, we challenged the gregarious behavior of a group of macroscopic aquatic agents, neon fish, by forcing the school to pass through a small opening[Larrieu, Sci. Rep. 2023]. Using a statistical analysis developed for granular material and applied to crowd evacuation, our results clearly show that, unlike human crowds or herds of sheep, no clogging forms at the bottleneck. The fish do not collide and wait by respecting their social distance and a minimum delay between two successive exits. In a second experiment, we perturbed the schooling behavior of a group of zebrafish by adding an array of pillars to the observation tank[Ventejou Phys. Rev. E 2024]. We observed a behavioral transition from a polarized group when the density of pillars is low to independent fish aligned with the array of pillars. The abrupt transition from natural to artificial orientation occurs when the distance between pillars is comparable to the social distance of the fish. We developed a stochastic model of relative orientation between pairs of fish that captures the behavioral transition and provides information on the evolution of cognitive parameters.