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Biological Physics Dissertation Award Talk - Self-organization in cytoskeletal mixtures: from synthetic cilia to flowing networks

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Inspired by biological functions such as ciliary beating and cytoplasmic streaming, we have developed a highly tunable and robust model system from biological components that self-organizes to produce a broad range of far-from-equilibrium materials with remarkable emergent properties. Using only simple components - microtubules, kinesin motor clusters, and a depletion agent that bundles MTs – we reproduced several essential biological functions, including cilia-like beating, the emergence of metachronal waves in bundle arrays, and internally generated flows in active cytoskeletal gels. The occurrence of these biomimetic functions as self-organized processes provides unique insight into the mechanisms that drive these processes in biology. Beyond these biomimetic behaviors, we have also used the same components to engineer novel active materials which have no biological analogues: active streaming 2D nematics, and finally self-propelled emulsion droplets. These observations exemplify how assemblages of animate microscopic objects exhibit highly sought-after collective and biomimetic properties, challenging us to develop a theoretical framework that would allow for a systematic engineering of their far-from-equilibrium material properties.