frontiers | Frontiers in Physics

TYPE Editorial
PUBLISHED 12 June 2023
DOI 10.3389/fphy.2023.1231716

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EDITED AND REVIEWED BY
Jasper Van Der Gucht,
Wageningen University and Research,
Netherlands

*CORRESPONDENCE
Amin Doostmohammadi,
doostmohammadi@nbi.ku.dk
Marco G. Mazza,
m.g.mazza@lboro.ac.uk
Tyler N. Shendruk,
t.shendruk@ed.ac.uk
Holger Stark,
holger.stark@tu-berlin.de

RECEIVED 30 May 2023
ACCEPTED 05 June 2023
PUBLISHED 12 June 2023

CITATION
Doostmohammadi A, Mazza MG, Shendruk TN and Stark H (2023), Editorial: Active and Intelligent Living Matter: from Fundamentals to Applications.
Front. Phys. 11:1231716.
doi: 10.3389/fphy.2023.1231716

Editorial: Active and Intelligent Living Matter: from Fundamentals to Applications

Amin Doostmohammadi[1]*, Marco G. Mazza[2]*, Tyler N. Shendruk[3]* and Holger Stark[4]*

[1]Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark, [2]Interdisciplinary Centre for Mathematical Modelling and Department of Mathematical Sciences, Loughborough University, Loughborough, United Kingdom, [3]School of Physics and Astronomy, The University of Edinburgh, Edinburgh, United Kingdom, [4]Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany

KEYWORDS

active matter physics, soft matter, liquid crystals, bacteria, self-organisation, amoeba

Editorial on the Research Topic
Active and Intelligent Living Matter: from Fundamentals to Applications

Equilibrium matter is the exception. Most physical systems in the Universe are out of equilibrium. Living organisms are the most complex and fascinating example of far-from-equilibrium matter, as they use energy to produce motion. But living matter does not simply move. It does so in response to cues and stimuli from their surroundings, integrates information, engages in collective responses to threats and produces complex behavior. All these phenomena point to the fact that, to fully understand living matter, one has also to address the most exquisite aspect of life: intelligent behavior.

Theoretical studies of model organisms can provide precious insight into fundamental principles of self-organization. Moreno et al., study *Dictyostelium discoideum,* a motile social amoeba, by means of a mathematical model coupling the internal biochemistry that couples the intracellular biochemical processes giving rise to membrane protrusions with the active motion of the amoebas. The authors employ a phase-field model that allows them to investigate deformable cell shapes and how this aspect feeds back to the motility patterns. They show that the internal biochemical kinetics has profound repercussions from single cell motion to clustering, on, and even on the aligning behavior, which is typically studied using geometry-based simplified rules.

Optimizing navigation strategies in complex environments is a situation common in the natural world where living systems have evolved to provide a number of ingenious solutions given their physical and biological constraints. Piro et al. in this Research Topic explore the benefits of Zermelo's policy in navigating a space exhibiting a sinusoidally varying external forcing. The authors, however, identify an interesting competition between the robustness of the policy and its efficiency in exploring the available space. This finding will inspire future works.

Unlike more complex organisms like eukaryotes, bacteria colonize space using simpler methods. At the most basic level, a bacterial colony grows by the simple growth and division of each cell, without active motility. Schwarzendahl and Beller study theoretically and with particle-based simulations growing bacterial colonies with steric interactions. They find that chaotic mixing is prevented in growth-driven colonies, as opposed to fixed-size active nematic fluids such as systems of microtubules. However, bacteria with larger aspect ratios have a stronger mixing ability than round ones. This finding is particularly suggestive of potentially important ecological implications. A consortium of microorganisms might be able to regulate symbiotic interactions by means of optimal growth-driven mixing abilities.

Control of active matter, taming the nonequilibrium fluctuations intimately linked with it, is one of the main driving forces of research in this field. Rajabi et al. present impressive results of control of the propulsion speed and direction of active droplet comprising *Bacillus subtilis* cells dispersed in a chromonic liquid crystal. The authors find that by leveraging the anisotropy of nematic liquid crystals together with a combination of electric fields and laser they can achieve dynamical control of the microswimmer propulsion. This is a considerable step forward with respect to previous approaches, where the control was typically achieved by static, pre-designed surface patterning. pave the way for a new way to tame the recalcitrant nature of active matter.

Active nematic behavior is a surprisingly powerful model of many living systems, e.g., cytoskeletal filaments. Houston and Alexander derive a novel mathematical formalism of “active nematic multipoles” to describe fundamental flow singularities that are representative of local distortions in active nematics. This approach is applicable to characterize topological defects loops and colloidal inclusions in active nematics. Fundamentally, by clarifying the mathematical underpinning of the net force and torque from multipoles the authors identify the self-propulsion and self-rotation generated by nematic distortions, and provide a roadmap to design specific dynamics and achieve targeted colloid delivery, a chief ambition of intelligent active matter.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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