Microswimmers and Self-Propelled Particles

Gerhard Gompper
Theoretical Soft Matter and Biophysics,
Institute of Complex Systems and Institute of Advanced Simulations,
Forschungszentrum Jülich, D-52425 Jülich, Germany;
email: g.gompper@fz-juelich.de

Abstract:
Both in soft matter and in biology, there are numerous examples of microswimmers and self-propelled particles. With a typical size in the range of tens of nanometers to several micrometers, both low-Reynolds-number hydrodynamics and thermal fluctuations are essential to determine their dynamics and their collective behavior. Prominent examples are sperm cells which are propelled by a snake-like motion of their tail, bacteria like *E. coli* which move forward by a rotational motion of their spiral-shaped flagella, and synthetic Janus colloids which catalyze a chemical reaction on their surface.
A powerful tool to study the non-equilibrium dynamics of microswimmers and self-propelled particles are mesoscale hydrodynamics simulation techniques, such as multi-particle collision dynamics (MPC), which have been shown describe the hydrodynamic behavior of many complex fluids – such as polymer solution, colloidal suspensions, and blood – very well.
The talk will focus on the cooperative behavior in systems of biological microswimmers, such as sperm, cilia, and bacteria, and on the effective attraction of microswimmers to surfaces. Sperm cell synchronize their beat and show a pronounced clustering behavior. Cilia beating in large two-dimensional arrays form metachronal waves, which strongly improve the fluid transport efficiency. The helical flagella of peritrichous bacteria synchronize and form bundles for propulsion, but also unbundle to induce bacterial tumbling. Finally, active particles display a strong surface excess in confined geometries. The effects of self-propulsion, hydrodynamic interactions, microswimmer shape, and noise on these phenomena will be discussed.