Researchers find best classroom shapes for fish swimming in schools

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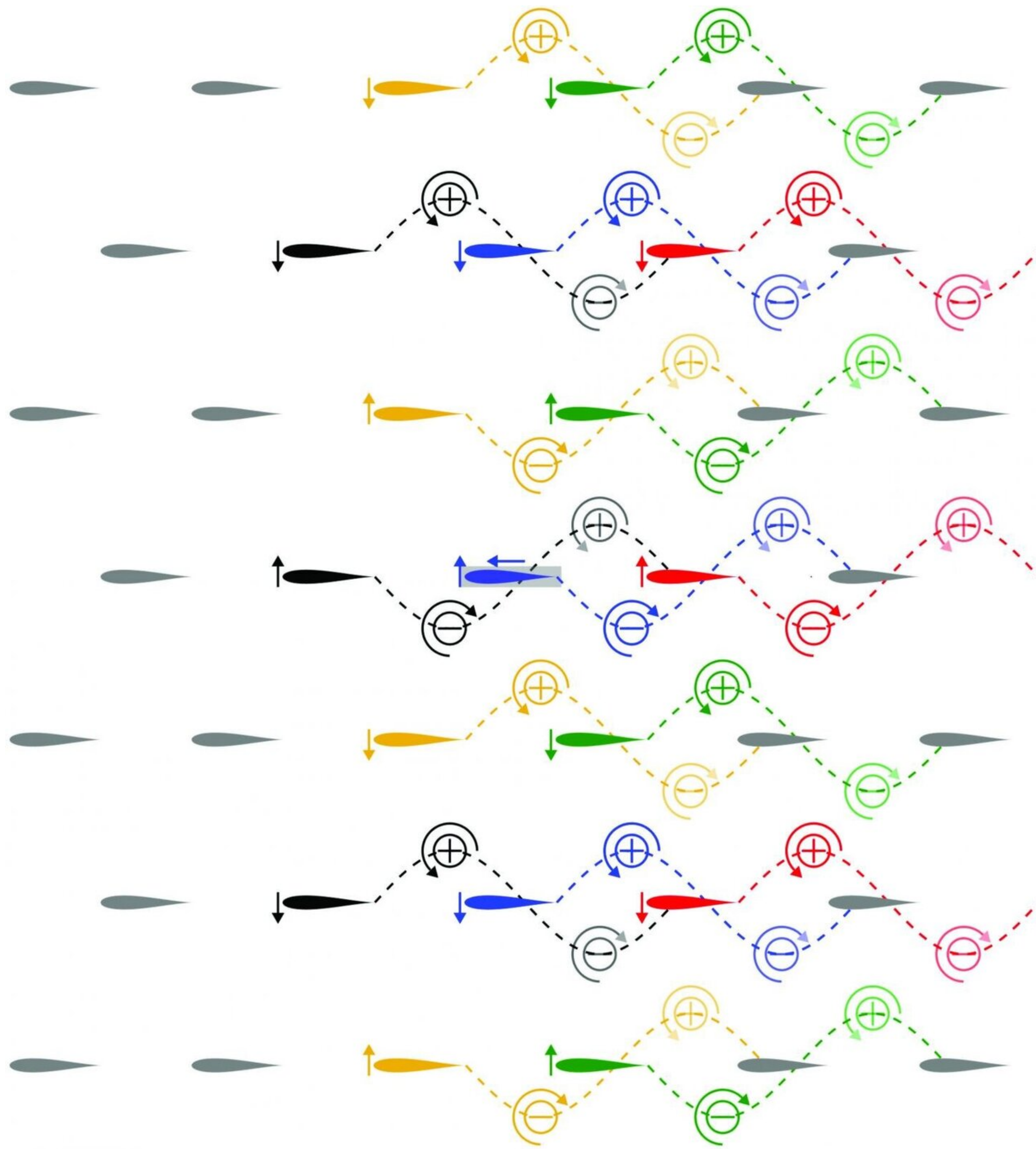

A depiction of an optimal school of swimmers in terms of speed and energy savings: a diamond-shaped lattice arrangement in which each fish has one direct upstream neighbor as well as two neighbors upstream and somewhat displaced to each side. The swimmers here are represented as wings that flap up and down and swim right to left. The plus and minus signs refer to the sense of rotation of the vortices or swirls that are generated by each swimmer. Credit: Anand Oza,

New Jersey Institute of Technology

A team of researchers has identified the best arrangements for fish swimming in schools—formations that are superior in terms of saving energy while also optimizing speed. Its findings, which appear in the journal *Physical Review X*, point to potential new ways to enhance energy-producing technologies.

The work, conducted by researchers at New York University's Courant Institute of Mathematical Sciences, also confirms a long-held belief: fish swimming in orderly groups or formations spend less energy and move faster than when swimming alone.

"Animals have figured out some interesting tricks that can save energy and move faster, and these behaviors could translate into new energy-harvesting and propulsion devices," says Leif Ristroph, an associate professor at the Courant Institute and one of the paper's co-authors. "Our model could inform how to optimize such technologies."

Using a new type of mathematical model, the team, which also included Michael Shelley, a professor at the Courant Institute, and Anand Oza, an assistant professor at the New Jersey Institute of Technology, focused on several arrangements of swimmers to see which were the best in terms of saving the energy required to swim and enhancing the speed of swimming for the group. In particular, using computer simulations, they examined how multiple flapping swimmers emit vortices, or swirling flows, and also interact with the vortex flows produced by others in the school.

In every school formation tested, the group of swimmers used less energy and moved faster than did solitary swimmers, with some notable differences among these arrangements:

- Phalanx arrangements, in which fish are lined up side-by-side, showed modest improvements over a solitary swimmer;
- Tandem formations, in which fish are lined up single file one after another, showed even more improvement over a solitary swimmer;
- Rectangular lattice formations—which combine the phalanx and tandem formations so that each fish has neighbors directly upstream, downstream and to either side—were superior to both the tandem and phalanx schools;
- Diamond-shaped lattices, in which each fish has one direct upstream neighbor as well as two neighbors upstream and somewhat displaced to each side, yielded the greatest speeds and largest energy savings—i.e., the best formation tested.

The researchers note that both the phalanx and diamond-lattice formations have been observed in fish schools, with smaller schools tending to adopt a phalanx formation and larger schools choosing a diamond lattice.

"By formulating a mathematical model capable of handling many swimmers interacting through their collectively generated flows, we think we have offered some concrete support for the idea that schooling fish may benefit from flow interactions," observes Ristroph. "We also hope to apply these same methods to other related problems—for example, flying formations of birds."

More information: Anand U. Oza et al, Lattices of Hydrodynamically Interacting Flapping Swimmers, *Physical Review X* (2019). DOI: 10.1103/PhysRevX.9.041024