Exploring the characteristics of viscoelastic fluids

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(PhysOrg.com) -- There are many microorganisms out there, navigating through complex biological fluids. “One of the most common migrations takes place with spermatozoa as it navigates the female reproductive tract,” Joseph Teran tells *PhysOrg.com*. “But there are other organisms that move through difficult environments as well, and we want to gain a better understanding of how these organisms move through viscoelastic fluids, like those found in biology.”

Teran works in the Department of Mathematics at the University of California, Los Angeles. He collaborated with Lisa Fauci at Tulane University and Michael Shelley at New York University to create a computer model depicting what happens when a free swimmer moves through a viscoelastic fluid. Their results can be seen in Physical Review Letters: “Viscoelastic Fluid Response Can Increase the Speed and Efficiency of a Free Swimmer.”

“Our experiment is a computer simulation that is more representative of the real medium than simpler models relying on a more standard Newtonian fluid. The simpler models work out nice mathematically, but they are not a very accurate description of the physics that are happening,” Teran explains.

With the simpler models, a wave is often depicted as moving through the fluid, with no head or tail. Additionally, these simpler models only account for the viscosity of the fluids, rather than including an element of elasticity. Teran and his peers added a free swimmer with a head and

a tail, and included information representing tail undulations. They also used a viscoelastic Boger fluid in their calculations to more accurately represent the actual conditions.

“What we found defies conventional wisdom,” Teran says. “When you think of a viscous fluid, like mud or honey, the fact that it is hard to swim through comes to mind. It’s inherently resistant to shear, and it is more likely to stop you. If you add elasticity, it seems like it should be even harder to swim through, since a viscoelastic fluid has a memory and resists changing shape. However, we found that a free swimmer ends up going faster in a viscoelastic fluid than a just plain viscous fluid.”

The answer lies in the tail motion of the swimmer. “If you accentuate the tail motion, as seen in a lot of microscopic swimmers, you see them able to move faster because they can use the elasticity in the fluid to sort of push off. It’s leverage for use in biology.”

Teran believes that the work he had done with Fauci and Shelley has implications for a number of biological applications. “The most obvious is in reproduction and fertility,” he points out. “Understanding how sperm locomote could be helpful in figuring out how to aid in reproduction. Teran also insists that understanding how these fluids work could have other uses in some engineering and biological functions. “There are a wide range of applications for fluids, and understanding their dynamics could be useful.”

Next, Teran, Fauci and Shelley hope to improve their model. “So far, we have only done this in a two dimension model,” Teran says. “We also used a Boger fluid, which is a kind of crude viscoelastic fluid. It’s simplistic and easier to tune to a given physical setting. But now that we know our model works, we want to ramp it up, improving the computer code. Three dimensional modeling is one natural extension, as is using a more complex fluid to even more accurately represent real world

conditions."

Hopefully, a better model will provide scientists and mathematicians with a better understanding of fluid dynamics. "Fundamentally, this could be a real help to science," Teran says, "and there are applications that could come out of this better understanding."

More information: Joseph Teran, Lisa Fauci, Mischael Shelley, "Viscoelastic Fluid Response Can Increase the Speed and Efficiency of a Free Swimmer," *Physical Review Letters* (2010). Available online: link.aps.org/doi/10.1103/PhysRevLett.104.038101