Swimming Bacteria Could Become Model for Micromachines

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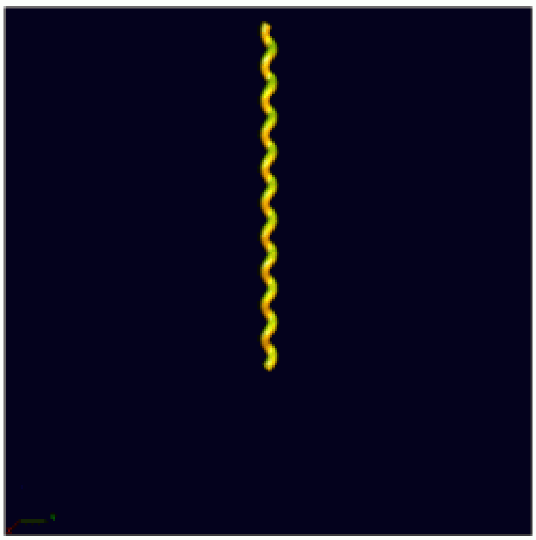

Using computer models, UConn researchers have pinpointed Spiroplasma's optimum swimming design. Click 'Enlarge' for animation.

(PhysOrg.com) -- UConn researchers say Spiroplasma's propulsion style is optimal for converting energy into motion.

The kinky motion of a primitive spiral-shaped bacterium in fluid could help design efficient swimming micro-robots of the future, according to a study by a team of UConn researchers.

Professors Greg Huber and Charles Wolgemuth of the Richard Berlin

Center for Cell Analysis & Modeling at the UConn Health Center, along with graduate student Jing Yang, have developed a computer model of the motion of Spiroplasma, which swims through fluid by sending kinks down its body.

The researchers believe the insights gained from this tiny bacterium could be used to design and engineer micromachines that might be used for microscale manufacturing or for medical procedures - currently a hot topic in nanotechnology. Their paper, "Kinematics of the Swimming of Spiroplasma," was recently published in the prestigious journal *Physical Review Letters.*

"There are potential applications to this study," says Huber, a biophysicist who studies how cells move. "It is possible that insights gained from this tiny bacterium could be used to design and engineer swimming micro-robots."

In the field of low Reynolds-number hydrodynamics - the study of fluid propulsion on tiny scales - researchers have become interested in the potential of building small artificial swimmers. Such swimming micro-robots could someday be used to deliver drugs or perform procedures on hard-to-reach sites within the human body.

But the microscopic world of the nano-swimmer is very different from the one we experience when going for a swim, Huber says. Because Spiroplasma operates at such a tiny scale, water that we move through relatively easily - thin and runny - is thicker to the nano-swimmers, more like tar. So the Spiroplasma meets a considerable amount of resistance to any sort of directed motion.

Many bacteria and other single-celled organisms have flagella or other propeller-like appendages, which they use to swim. The flagella are essentially powered by "motors" embedded in the bacterium's cell wall.

If the motors all rotate counter-clockwise in a viscous liquid like water, the flagella bundle together and push the organism forward in an approximately straight line.

However, the 200 nanometer-wide and few micron-long Spiroplasma, small even by bacterial standards, lacks any external means of propulsion. It is different from other bacteria in the sense that it has neither a rigid cell wall nor flagella, but rather moves using its body as one giant flagellum - continually changing its body shape to push itself forward.

The exact method of Spiroplasma's locomotion was a mystery until 2005, when researchers looking at high-speed videos discovered that it moves through water by sending a pair of kinks down its body, as it switches its body from a right-handed helix to its mirror-image left-handed form, and vice versa. The net effect is a zig-zagging forward motion.

"We wanted to understand the underlying physics of these contortions," Huber says. "The complex interaction between fluid media and the deformable propulsive elements leads to challenging physical questions.

"Especially difficult to solve are situations with elastic, flexible objects - when the flows influence and are generated by flexible objects," he says. "There's a kind of feedback between force and response, and we are just learning how to handle these with the mathematical tools at our disposal."

To examine the relationship between Spiroplasma's unique body design and swimming efficiency, Huber and his colleagues created a computer model that would allow them to determine what was the optimal shape and swimming strategy - the organism's cell length, the size of the kink-induced bend, and how fast the kink travels down the body - for fast swimming on the micro scale.

Their calculations showed Spiroplasma's kinky propulsion style is perfectly suited for efficiently converting energy into motion.

"We have shown that the observed shape and kinematics of Spiroplasma are very near to what maximizes its overall swimming velocity," Huber says. "We estimate this kinky means of mobility pushes the Spiroplasma through liquid at speeds of about three to five microns, or about a body length, per second.

"Fuel mileage is a term more often heard on the lots of car dealerships than in microbiology departments," Huber adds. "However, just as you'd like to maximize your car's miles per gallon, a microorganism might want to maximize the distance traveled per energy expended. Our model shows that for Spiroplasma, evolution has done just that."

More information: Paper online: scitation.aip.org/getabs/servl … dtype=cvips&gifs=yes

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