Female reproductive tract assists swimming sperm

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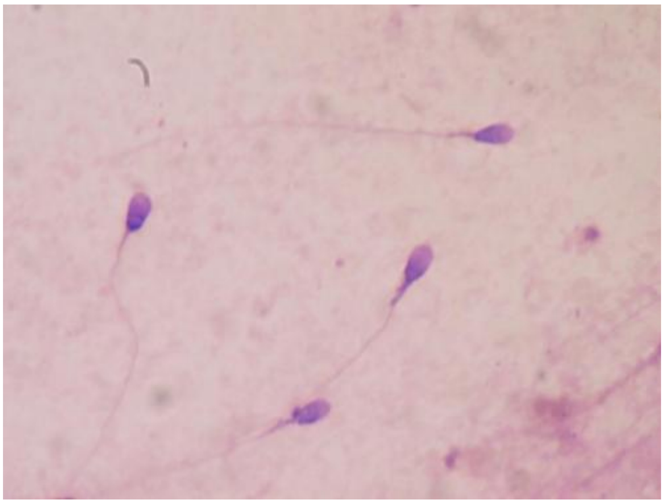

Human sperm stained for semen quality testing in the clinical laboratory. Credit: Bobjgalindo/Wikipedia

In mammalian reproduction, sperm have a tough task: like trout swimming upstream, they must swim against a current through a convoluted female reproductive tract in search of the unfertilized egg.

Many fertility studies focus on how fast sperm swim, but a new study shifts that focus to the physical environment of the female body. The collaborative work was led by Mingming Wu, associate professor of biological and environmental engineering, and Susan Suarez, professor of biomedical sciences in the College of Veterinary Medicine.

Their study asserts that, in the presence of a gentle fluid flow, the biophysics of the female reproductive tract – in particular, the grooves that line parts of it – critically guide sperm migration without aiding the migration of pathogens. The study was published online April 13 by *Proceedings of the National Academy of Sciences*, with first author Chih-kuan Tung, a postdoctoral associate in Wu's lab and a physicist.

The study also showed that sexually transmitted pathogens that infect humans and cattle with trichomoniasis are swept safely away under the same fluidic conditions. The findings point to the co-evolution of sperm motility and the female reproductive tract, and could lend new insight into fertility treatments by shifting focus to the physics of the interaction of sperm with the female reproductive tract.

Sperm are "pusher microswimmers." With an asymmetrical body and one rear flagellum, sperm propel themselves forward while rotating like a screw. In an earlier paper in Physical Review Letters, the researchers found that the sperm's upstream swimming ability relates to this flagellar pushing motion coupled with hydrodynamic interaction with surfaces.

For the *PNAS* study, the researchers applied the idea. Tung led the design of a microfluidic device that mimics the biophysical environment of the two junctions in the female reproductive tract, the cervix, and the junction between the uterus and oviduct, or fallopian tube. They modeled the bovine tract, which is structurally similar to humans in this regard. Tung used data provided by Suarez's group, which studies how sperm move through the female tract. The device, about 4 centimeters in length, was carved with 10-20 micron-wide grooves that are found in the female reproductive tract.

They found that when sperm swam against a current similar to the downward current found in the female reproductive tract, the sperm tended to enter microgrooves and swim through them against the direction of the flow. The microgrooves shielded them from the larger flow, which is how they use the microgrooves to help them along their journey.

In contrast, bovine pathogens called Tritrichomonas foetus didn't enter the microgrooves, and thus were washed away by the fluid flow. T. foetus, which has a counterpart, Tritrichomonas vaginalis that infects humans, is a puller microswimmer, because it mainly uses its front flagella to pull itself forward.

"Often fertility treatments are focused on the chemicals that will help sperm swim better," Wu said. "This is a paradigm shift into thinking more about fluid flow and physical forces."

Ever since reading a paper in 1989 by June Mullins and Richard Saacke of Virginia Tech, in which they described the presence of microgrooves filled with sperm in the cervixes of cows, Suarez had been interested in addressing the question of whether microgrooves provide guiding pathways for sperm. The development of microfluidic technology enabled her to address this question.

"I was thrilled to work with Drs. Tung and Wu to develop and use these devices to finally test the hypothesis," Suarez said. "Finding that the trichomoniasis pathogens did not enter these grooves was also exciting, because it illustrates how males and females co-evolve to facilitate fertilization while reducing infection by sexually transmitted pathogens."

The work ties in with Wu's other research interest in the microenvironment of tumor cells – a growing field that employs not only genetics and chemotaxis of tumor metastasis, but also the physical cues that allow tumor cells to grow, change and migrate.

The research collaboration began about five years ago with a seed grant from the Cornell Nanobiotechnology Center, funded by the National Science Foundation, which encourages collaborations between life sciences and physical sciences. The work has since been supported by the National Institutes of Health. The paper is titled "Microgrooves and fluid flows provide preferential passageways for sperm over pathogen Tritrichomonas foetus."

More information: "Microgrooves and fluid flows provide preferential passageways for sperm over pathogen Tritrichomonas foetus." *PNAS* 2015 ; published ahead of print April 13, 2015, DOI: 10.1073/pnas.1500541112

"Emergence of Upstream Swimming via a Hydrodynamic Transition." *Phys. Rev. Lett*. 114, 108102 – Published 13 March 2015. dx.doi.org/10.1103/PhysRevLett.114.108102

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