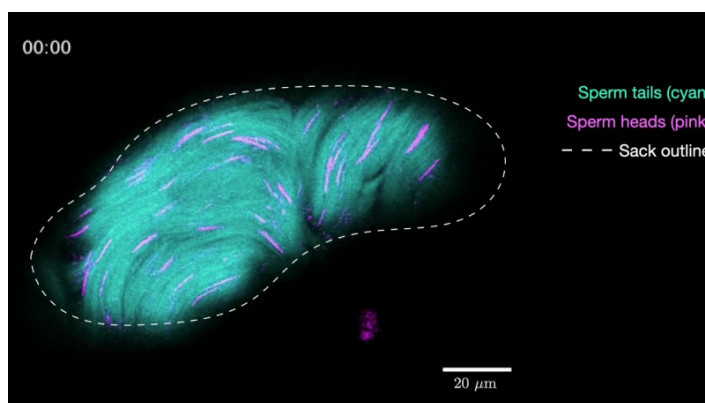


Videos Reveal the Secret to Giant Sperm Packing

The exceptionally long sperm of fruit flies are able to fit in their small storage organ by swimming in opposite-direction lanes, new experiments show.

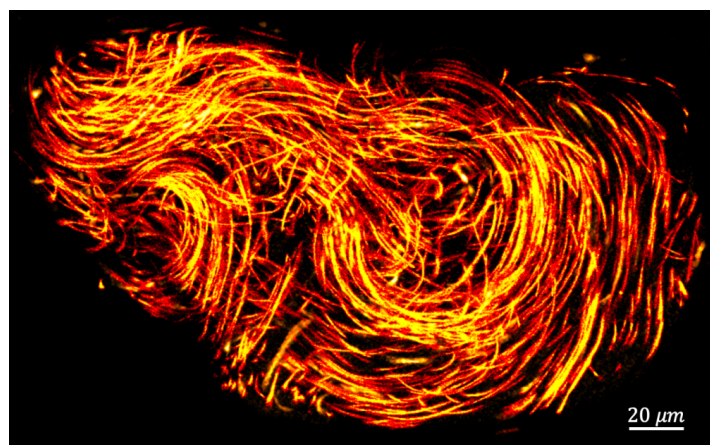
By **Michael Schirber**

The unassuming male fruit fly produces sperm cells that are as long as its entire body. More surprising still, the fly can store thousands of these 2-mm-long cells in a tiny reproductive organ only a tenth as wide as the cells are long—without them ever knotting up. Researchers have now unpacked this packing trick using videos of fluorescent sperm inside live organs [1]. The observations show that the sperm cells are folded within the organ but remain aligned with their neighbors, swimming in opposite directions like cars driving on a two-way highway. The team’s modeling shows how this organization can help the sperm swim fast while avoiding tangles.



A 2D movie of the seminal vesicle, showing sperm with labeled heads (pink) and tails (cyan). Individual sperm move smoothly past each other, like cars on a highway.

Credit: J. Imran Alsous/Flatiron Institute



This snapshot shows fluorescently labeled sperm swimming inside a male storage organ. The cells align with each other without forming knots.

Credit: J. Imran Alsous/Flatiron Institute

In humans and other mammals, sperm are around 50 μm long, but in certain organisms—including insects, snails, and shrimp—they can reach several centimeters in length. The factors driving the evolution of giant sperm vary across species, but in the common fruit fly (*Drosophila melanogaster*), competition among sperm is the main one. Female fruit flies mate with several males, storing the received sperm in a specialized organ prior to fertilization. “Competition doesn’t stop at mating. The sperm have to duke it out inside the female,” explains Jasmin Imran Alsous from the Flatiron Institute in New York. And in the female reproductive system, longer sperm have an advantage [2].

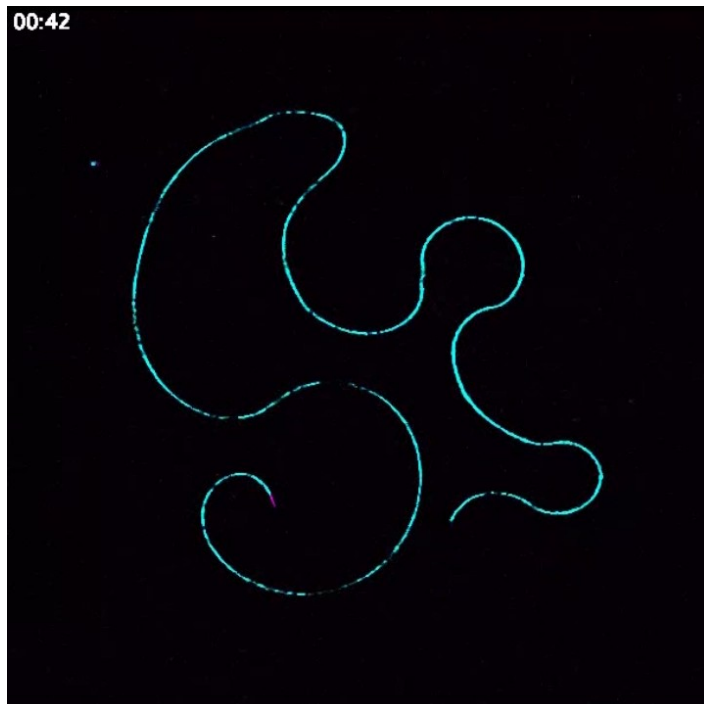
But if that's the why, the next question is how: How can flies store large numbers of giant sperm in such tiny organs? Imran Alsous and her colleagues decided to find out using a genetically engineered fruit fly that produces fluorescently labeled sperm (one color for the heads; another for the tails). From each fly specimen, the researchers extracted the seminal vesicle (the small organ where male flies store their sperm) and placed it under a microscope. "These sperm are moving smoothly past one another and continuing to do so over several hours," Imran Alsous says. The researchers performed similar experiments on female-fruit-fly sperm-storage organs and saw similar behavior.

Further analysis found that the average sperm speed is about $15\text{ }\mu\text{m/s}$, which was surprising, as an isolated fly sperm doesn't move much at all: It writhes back and forth but doesn't advance in any direction, explains team member Brato Chakrabarti from the International Center for Theoretical Sciences in India. "However, when you put the same sperm in a highly packed environment, it becomes motile," he says.

The researchers developed a model to explain this behavior. They assumed that each sperm has an imaginary tube around it, formed by its neighbors. Each sperm moves through their tube by generating waves in its tail and by interacting with the wiggling sperm in nearby lanes. "It's like the sperm are moving through a very crowded pool by pushing off of their closest neighbors," Imran Alsous explains.

The researchers contrast this with the motion of human sperm, which generate thrust by whipping their tails back and forth and pushing off the surrounding fluid. Human sperm can swim by themselves, but fruit-fly sperm exhibit directional motion only in a group.

The observed behavior is similar to "reptation," the snake-like motion of macromolecules in polymer solutions. By moving in opposite directions relative to their neighbors, the sperm cells generate a force that stretches out individual sperm. This stretching is what prevents the sperm from getting entangled in knots, Chakrabarti explains. He gives the analogy of DNA packed inside a cell nucleus, where similar knot-preventing



An isolated fruit-fly sperm generates wave motion in its tail (cyan), but without other sperm around, its head (pink) doesn't advance.
Credit: J. Imran Alsous/Flatiron Institute

stresses are believed to arise from enzymatic activity [3].

"This is a stunningly important contribution to reproductive biology because it finally tackles the functional biology of sperm within the complex social and spatial environments of the male and female reproductive tracts—no easy task," says giant sperm expert Scott Pitnick from Syracuse University in New York, who was not involved in the study.

He points out that there exists wide variation in fruit-fly-sperm morphology, with one species (*Drosophila bifurca*) having sperm that are 58 mm long—almost 30 times that of *D. melanogaster*. "We desperately need to resolve how variation in sperm form translates into functional advantages for fertilization against competitor sperm within the female," Pitnick says. "This study paints a very encouraging path forward."

Imran Alsous is also intrigued by the amazing diversity of sperm cells across organisms. "Sperm are among the few cells that

have to continue to function outside the body that made them,” she says. The challenges of surviving in this external environment have made sperm cells very adaptable. And one adaptation is knowing how to avoid tying the knot with your neighbors.

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