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Pond dwellers called Euglena swim in polygons to avoid light

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In any seemingly quiet pond the still waters actually teem with tiny pond dwellers called Euglena gracilis. Unseen to the naked eye, the single-celled organism spirals through the water, pulled along a relatively straight path by a whiplike appendage in search of just the right level of light.

But a new paper published Sept. 24 in *Nature Physics* describes how, under some circumstances, Euglena halts its forward progress and begins tracing out elaborate counterclockwise polygons – triangles, squares, pentagons – in a mathematically defined effort to find a better environment.

The discovery, led by Ingmar Riedel-Kruse, assistant professor of bioengineering at Stanford University, could help scientists design tiny swimming robots of the future to be more efficient and effective at maneuvering through the bloodstream, for example, or navigating watery environments.

"We're trying to understand biological systems in a mathematical way," Riedel-Kruse said. "Seemingly simple feedback loops in single cells can actually generate rather complex behaviors in order to accomplish various tasks."

Well-studied organism

Scientists in the 1800s once marveled at finding Euglena – a greenish oblong with a red eyespot and long, whiplike flagellum for swimming – under a microscope. Since then, the organism has been observed by countless generations of biology students. With such a history of being watched, it came as a surprise when postdoctoral fellow Alan Tsang first noticed Euglena's novel behavior in a computer model he'd developed to study how it moves in relation to light. In his model, when he simulated increased light, the organism began tracing out polygons.

Riedel-Kruse remembered being skeptical when Tsang first described what his model predicted.

"It was hard to believe that it's true," Riedel-Kruse said. "I thought there was something wrong with the code." But when the pair checked under the microscope – increasing light levels as in the simulation – there were the polygons.

The shapes are a result of how Euglena navigates the world. Because the organism normally rolls through the water on its long axis, the eyespot rotates to survey 360 degrees of light. In steady light conditions – which is normal under a microscope – it meanders along in a relatively straight path.

However, Tsang said, if the eyespot detects increased light intensity, the Euglena makes a hard turn.

"Then they don't see the light and they swim straight again," Riedel-Kruse said. "But since they keep rolling, then after a full cycle they see again the strong light so they make another strong side turn."

Enough straight lines followed by sharp turns and a triangle is born.

Tsang noticed that over the course of about 30 seconds, Euglena adapted to the stronger light and the turns became less sharp, creating ever-expanding polygons – squares, then pentagons – until, finally, the Euglena headed in a relatively straight line.

As for why nobody had seen this before, Riedel-Kruse said people rarely alter light levels while observing Euglena under a microscope. But since Tsang was specifically trying to model how the organism moves in relation to light, he did something unusual and the behavior appeared.

A novel behavior

Riedel-Kruse argued that the behavior makes sense for a Euglena swimming along in a pond under a comfortable source of shade. When it suddenly encounters bright sunlight it can turn quickly to seek a patch of shade. By slowly spiraling outward if the first few turns didn't work, the Euglena ups its chances of eventually getting out of the sunlight.

Riedel-Kruse's lab studies Euglena in part to better understand how microorganisms navigate their watery worlds. The researchers also integrate what they learn about Euglena into interactive biology setups for education. Euglena is an unusual organism that can both make its own food and eat what it finds in the water. It is related to plants, animals and fungi – all known as eukaryotes – but is a separate group with some unique characteristics.

"Because it is part of an outgroup to most eukaryotic life, you could learn something that is general, and you can also find out how diverse eukaryotic life can be," Riedel-Kruse said. "That makes Euglena really interesting to me."

What's more, Riedel-Kruse and Tsang said what they learn – and the mathematical models they developed – could be useful for microscale robotics.

"There is an emerging field where people are trying to engineer and program microscopic swarm robotics for things like microsurgery or drug delivery," Tsang said. "I definitely see people looking for efficient control mechanisms at the microscale."

More information: Alan C. H. Tsang et al. Polygonal motion and adaptable phototaxis via flagellar beat switching in the microswimmer Euglena gracilis, *Nature Physics* (2018). DOI: 10.1038/s41567-018-0277-7

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