

Long-necked single-celled predator has mastered an unusual origami fold

The tiny organism is nature's version of a bendy straw.

Imagine if you could stretch your arms or neck by a third of the length of a football field in just seconds to grab a snack. The single-celled organism *Lacrymaria olor* can do the scaled-down version of just that. Normally about 60 μm long, the cell regularly extends a necklike appendage up to 1.2 mm to hunt prey.

Single-celled shape-shifters aren't uncommon, but *L. olor* stands out for its speed and reversibility: The full extension-retraction cycle takes 30 seconds and can be repeated more than 20 000 times in the cell's lifetime. The cell isn't encumbered by bones or a spinal cord, but it still has a cytoskeleton and an unstretchable cell membrane, which would seem to preclude such rapid shape change. The neck extends and contracts far faster than the cell can construct new membrane material. Where does all the extra membrane come from? And what physical processes govern the change?

Stanford University's Elliott Flaum and Manu Prakash now shed light on those questions. Their fluorescence-microscopy images in figure 1 show that *L. olor*'s cytoskeletal filaments are wrapped helically around the cell. When they looked more closely, they saw something extraordi-

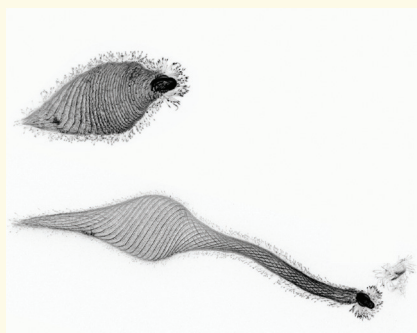


FIGURE 1. THE PROTIST LACRYMARIA OLOR can extend its neck to some 20 times its body length and reversibly retract it in seconds. Essential to its extraordinary ability are the helical cytoskeletal filaments, shown in these color-reversed fluorescence-microscopy images, and the cell-membrane pleats between them. (Courtesy of Elliott Flaum and Manu Prakash.)

nary: In the gaps between the filaments, the cell membrane was doubled over on itself in pleats, which unfolded as the neck extended and refolded when it contracted.

The pleated membrane's mechanical properties can be understood in terms of curved-crease origami. Unlike more typical straight folds, which can be partially unfolded to any angle with no energetic penalty, curved creases are often bistable, and they pop between completely folded and completely unfolded states. The phenomenon can be seen in the circular pleats in a bendy drinking straw, shown schematically in figure 2a. But whereas bendy-straw pleats pop one by one at random, *L. olor*'s helical pleats pop all at once, but only

partway down the length of the cell, as shown in figure 2b.

Curved-crease-origami energetics go a long way toward explaining how *L. olor* can extend and retract its neck so quickly: Cilia at one end of the organism get the unfolding started, and mechanics and geometry take care of the rest. *L. olor* is not the first unusual single-celled organism that Prakash and his group have studied (see *Physics Today*, September 2019, page 22), and it likely won't be the last. As he notes, the microbiological world has many thousands more species whose unique behaviors remain to be studied. (E. Flaum, M. Prakash, *Science* **384**, eadk5511, 2024.)

Johanna Miller

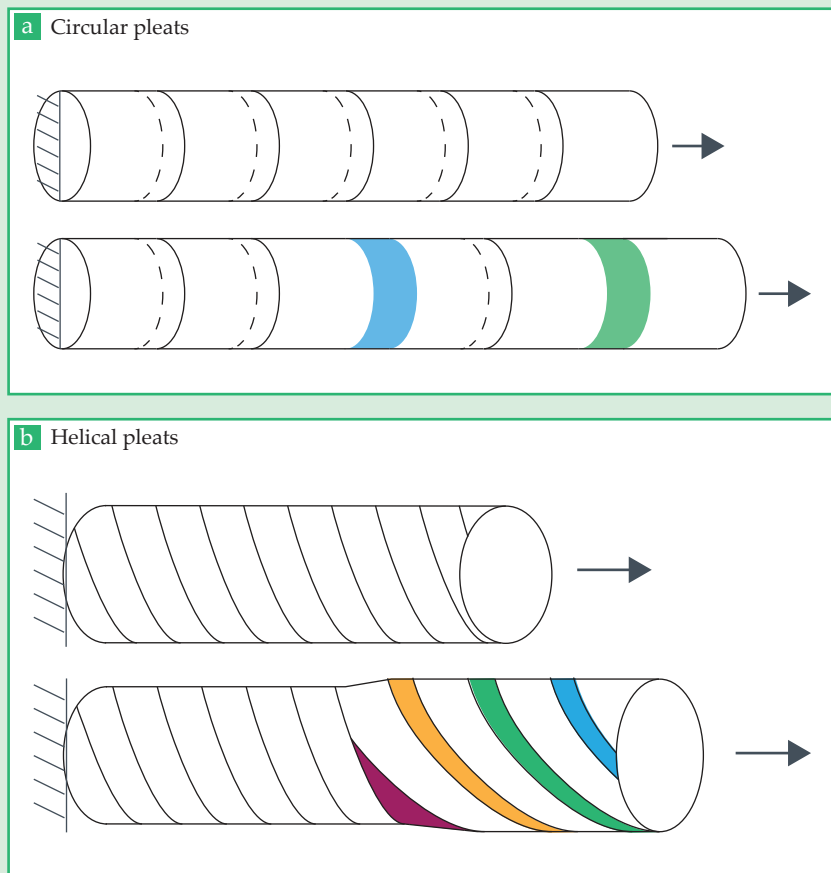


FIGURE 2. BENDY STRAWS AND PREDATORY CELLS both rely on the mechanics of curved creases. The circular pleats of a flexible straw, shown in (a), pop from folded to unfolded one by one. The helical pleats of *Lacrymaria olor*'s cell membrane, shown in (b), behave slightly differently. In their paper's supplementary information, Elliott Flaum and Manu Prakash include detailed instructions for readers to build their own paper model of the spiral-pleated cell. (Adapted from E. Flaum, M. Prakash, *Science* **384**, eadk5511, 2024.)