UC SANTA BARBARA

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Soap Opera

A pool of red dye is suspended in a coaster-sized maze filled with milk. Then liquid soap is dropped in, causing the dye to move, not just along the passages, but to actually “solve” the maze. It takes the appropriate directions, even making right-angle turns, until it exits the labyrinth.

How? It’s the Marangoni effect, or, what happens when you put fluids of varying surface tensions next to one another, creating a gradient of surface tensions.

And it’s all been caught on film, courtesy of UC Santa Barbara researchers, who have won an award for their efforts. Doctoral student Fernando Temprano-Coleto and colleagues demonstrate fundamental fluid mechanics in a three-minute video recognized by the American Physical Society’s Gallery of Fluid Motion for its “combination of striking visual qualities and scientific interest.”

“[The Marangoni effect] is also responsible for slowing down air bubbles rising in water, or for the ‘tears’ that wine forms on the wall of a glass,” said UCSB mechanical engineering professor Paolo Luzzatto-Fegiz, who co-advises Temprano-Coleto together with professor Frederic Gibou.

You’ll perhaps remember from science class the phenomenon of surface tension. It’s the force that makes water droplets or soap bubbles retain their spherical shapes, and the reason some denser-than-water objects (such as leaves or insects) can float on the surface of a pond. It refers to the molecules’ ability to pull on surrounding molecules — the higher the tension, the stronger the pull.

“Soap is well-known in the fluid mechanics community for being a surfactant,” Luzzatto-Fegiz said. Its ability to lower surface tension can induce motion on a liquid surface that would otherwise remain at rest, he explained.

As soap is dropped into the red dye, as in their video, it lowers the local surface tension, loosening the bonds between the fluid molecules in the area. At the same time, the relatively higher surface tension of the surrounding milk pulls on the dye, propelling those molecules into areas of higher surface tension — the Marangoni effect.

But that’s only part of it. According to the researchers, the apparent ability of soap to always choose the correct way to turn in a maze could be explained by the presence of endogenous surfactants.

“These are very small amounts of other surfactants that are already present on the milk surface before the addition of the soap,” Temprano-Coleto said. As the drop of dye progresses in the maze toward the outlet, he continued, it compresses the surface of the liquid ahead of it, squeezing the endogenous surfactants over a smaller surface area. The concentrated surfactants at the head of the dye create a resisting Marangoni force, opposing the one that is pushing the dye forward.

“When the dye reaches a bifurcation it naturally chooses the path of least resistance, which is the one with the largest surface area ahead because that one minimizes the accumulation of endogenous surfactants,” he said. “Indeed, the large size of the outlet reservoir of the maze offers the least resistance at every bifurcation, thus enabling the soap to solve the maze correctly.”

The hypothesis still needs to be fully corroborated, the researchers said. However, there is mounting evidence that unavoidable traces of surfactants can crucially affect flows in important industrial applications such as the drag reduction potential of superhydrophobic surfaces, which Luzzatto-Fegiz and collaborators recently demonstrated (Peaudecerf et al., PNAS 114 (28), 2017).

The maze experiment is a joint project between UCSB researchers and Julien Landel at the University of Manchester, as well as François Peaudecerf at ETH Zurich, with additional contributions from Oliver Jensen at the University of Manchester.

About UC Santa Barbara

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