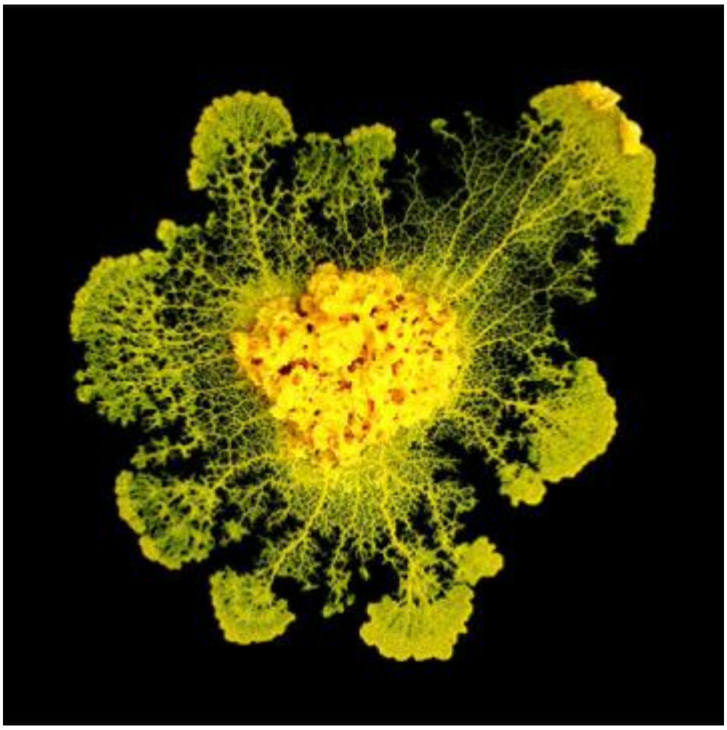
This weird, slimy single-cell organism can learn — without a brain



The slime mold Physarum polycephalum

Never in nature has a creature been more poorly served by its name than the lowly slime mold. "Slime mold." Sounds boring, right? Maybe a little gross? Maybe like you'd rather not be thinking about it right now, or ever? Well, friends, prepare to be amazed. The slime mold is way, way more impressive than you think.

Take, for example, the *Physarum polycephalum*, or "many-headed slime" (a much better name, by the way). It's a single-celled organism with no brain to speak of, but it's capable of solving mazes, maintaining a balanced diet, and even "designing" an efficient railway system.

It's also capable of learning something new, researchers report this week in the journal Proceedings of the Royal Society B — a discovery that might help change our notion of what intelligence really means.

Learning "is something that we thought was very complicated," said lead author Romain Boisseau, a behavioral ecology student at the Ecole Normale Supérieure in Paris. "You know, it requires a lot of neurons and connections and a brain."
"But maybe the fact that it is happening at the level of one cell indicates that this process we thought was complex might be enabled by a simple mechanism," he continued. This mechanism could have evolved very early in life. It could be more universal than we realized.

"Which would be awesome," Boisseau said.

Granted, the slime molds weren't schooling themselves in differential calculus or Shakespearean literature. What these primitive, soil-dwelling creatures showed was a very basic kind of learning called habituation — a diminishing response to an irrelevant stimulus. Your new puppy demonstrates habituation when it stops barking every time a car drives by your window; after weeks of hearing traffic zoom past with no negative consequences, it learns that the sound of a motor is nothing to worry about.

In slime molds, habituation was tested with two bitter but otherwise harmless chemicals, quinine and caffeine. Boisseau and his colleagues put the organisms in an agar dish, then built a chemical-covered bridge to a second dish with food in it. The slimes (which, despite being single-celled, are exceptionally large — some have thousands of nuclei and can grow as big as several meters across) were initially reluctant to venture over the bitter pathway.

[Could a computer run on slime mold?]

On the first day of the experiment, the slimes waited until they'd exhausted all other options before extending a single, thin tentacle over the bridge to examine what was on the other side. Only then did they slowly and reluctantly transport their blobby bodies over the bridge, carefully keeping to the narrow path made by the initial exploratory tentacle. The whole ordeal took them 200 minutes — more than triple the amount of time it took a control group to make a crossing over a bridge that hadn't been chemically treated.

But by day six, realizing that a little quinine or caffeine wouldn't kill them, the slime molds cut their crossing time in half. They migrated over the bridge in a big blob rather than a cautious trickle, seemingly deciding that avoiding exposure to the bitter substance just wasn't worth the effort.

To make sure that the slime molds hadn't simply gotten too tired for an elaborate routine, Boisseau switched the chemicals they were exposed to. Ones that had been trained on quinine were now forced to confront caffeine, and vice versa. Both returned to their timid-tentacle way of crossing the bridge, suggesting that it was habituation, not laziness, that got them to cross so carelessly.

Boisseau ticked off the three steps of the procedure: The slime molds were exposed to a stimulus, understood its effect, and then changed their response accordingly.

"This is what I consider learning," he concluded.

The study is just one piece of a building body of evidence that slime molds don't need a nervous system to show a range of complex and seemingly brilliant behaviors. These members of the informal taxonomic group "protists" — which biologists often joke is shorthand for everything they don't understand — may have evolved as early as a billion years ago, before even the very first multi-cellular organisms.

But it's only in the past half century that they've been "redefining what you need to have to qualify as intelligent," as behavioral ecologist Chris Reid told Scientific American in 2012.

The University of Sydney researcher was speaking about his work on slime mold navigation. In a study he co-authored with French scientist Audrey Dussutour (who was also one of the authors on the habituation study), Reid found that foraging slime molds leave a chemical trail of sticky slime wherever they go in order to avoid retracing their steps later on. They'd managed to externalize the process of spatial memory making, allowing them to achieve tasks — like navigating a labyrinth — that would tax the nervous systems of far more sophisticated creatures.

Other studies have found that slime molds have an intuitive understanding of efficiency. When scientists in Japan placed them on a "map" with clusters of food of varying sizes positioned in the place of Tokyo and its suburbs, the slime molds moved to form a network that was startlingly similar to the city's actual railway system. The same experiment has been done to simulate the highways of the United Kingdom and the effects of a nuclear disaster in Ontario.

“If some countries started to build highways from scratch, I would recommend to them to follow the slime mold routes,” Andrew Adamatzky, director of the Unconventional Computing Center at the University of West England, once told the New York Times.

Princeton biologist John Tyler Bonner has been studying slime molds longer than almost anyone. Beyond being startlingly smart, these organisms are curiously convivial, he's found. When a single slime mold is split in half, the two segments will crawl toward each other until they can reunite again.

They also exhibit a rudimentary form of altruism: When they want to disperse, a cluster of slime mold cells will form a stalk that reaches up from the soil and provides a launch site for spores to cast themselves into the breeze. The bottom 20 percent of cells in the stalk die in the process, martyred so their relatives could survive. Sure, this phenomenon isn't entirely self-sacrificial — researchers note that, by dying for their brothers, the cells are helping to ensure that their genes live on. But it's still pretty sophisticated for a creature that lacks a single neuron, let alone a brain.

"Slime molds are pretty awesome," said Boisseau, the author of the habituation study. Their capacity for navigation, organization and possibly even learning should shake some of our assumptions about intelligence, he added. Humans may like to think that we're far more evolved than an organism like a slime mold, but they seem to have some of the same skills that we do.

"They evolved that ability probably in a different way than us, but the function is the same," he said.

Perhaps learning isn't so complicated after all. Or maybe it's just that slime molds aren't as simple as they seem.