Science Observer

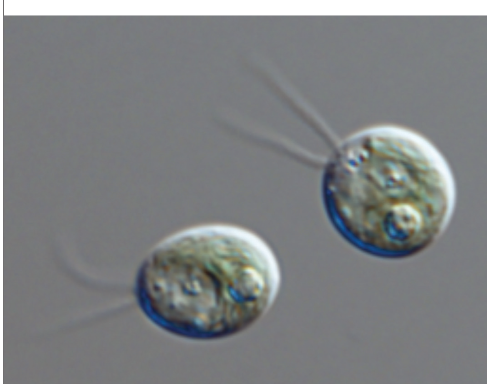
Dying Generously

For some single-celled organisms, self-destruction is neighborly

Suicide is an evolutionary conundrum. Single-celled organisms regularly kill themselves in reaction to stresses they might have survived, but it's not obvious why natural selection permits such volatile behavior.

One explanation, that suicide can benefit neighbors and relatives of the deceased cell, got a boost with new experiments published in the February issue of *American Naturalist*. Working together at the University of Arizona, Pierre Durand, Armin Rashidi and Richard Michod found that when the unicellular alga *Chlamydomonas reinhardtii* dies by suicide, it releases compounds that help surviving cells grow faster.

In multicellular organisms, programmed cell death (PCD) demands no special explanation because it's not really suicide. The whole organism has to survive and reproduce, and its component cells should do whatever it takes to help. In humans, for example, PCD shapes fingers, blood vessels and other anatomical features during development, and eliminates damaged cells throughout life.



If these *Chlamydomonas reinhardtii* cells were to die suddenly, they would spill toxic contents into their environment and harm nearby cells. But when they die by suicide, or programmed cell death, they instead release compounds that help surviving cells multiply faster. (Photograph by Deborah Bock, courtesy of Pierre Durand.)

When an individual cell is also an entire organism, however, PCD is counterintuitive—so much so that when biologists discovered suicide in marine algae, they were met with skepticism. "For the longest time, people didn't even believe that this pathway existed in these organisms because they were unicellular," says Kay Bidle, a molecular ecologist who studies marine algae at Rutgers University.

But the discovery was no fluke. Several years later, researchers have found PCD everywhere they've looked. Fungi, protozoans, red and green algae, and even bacteria have genetic programs that, when activated, orchestrate self-destruction. Suicidal cells actively expend energy to shrink, chop up their own DNA and engineer other fatal changes.

Although premature death has turned out to be common in single-celled organisms, biologists still struggle to explain it. "If there's a chance of you surviving you should do it," says Michod. But if in death, a cell could benefit other individuals that share its genes, natural selection might keep suicidal traits in the population.

To test this hypothesis, the team grew three clonal cultures of *C. reinhardtii*. They plunged one flask of algae into a water bath of 50 degrees Celsius for 10 minutes. That's enough to start scalding human skin and to launch *C. reinhardtii's* death program. Within less than a day, those cells had all perished, and showed telltale signs of suicide, such as chopped-up DNA.

The second culture died by necrosis—that is, sudden "unplanned" death during which cells dump their contents into the environment unaltered. To simulate necrosis, the team used a sonicator probe to tear the algae apart with high-pitched sound waves. Michod acknowledges that sonication was an artificial way of killing the cells. But, he says, it was the only assault they could conceive that would kill the cells before they could even start PCD.

The third culture, the control, enjoyed a normal unstressed life for another 18 hours. Then the team supplemented new *C. reinhardtii* cultures with the liquid in which suicide, necrosis, or business as usual had transpired. In a final control, some cultures got fresh nutrient broth with no supplement. "It was very dramatic," Michod says. Over dozens of replicate experiments, the leftovers from PCD made cells grow faster than did fresh nutrient broth or leftovers from the control culture. Depending on the concentration, the PCD supplement could double a culture's growth over four days.

The broth contaminated by necrosis, on the other hand, was a potent growth inhibitor. "Cells carry a lot of toxic things," Michod says. If those contents, such as chlorophyll, enter the environment unaltered, they poison the neighbors. Still, it's not clear how PCD rendered chlorophyll harmless and liberated growth-enhancing compounds. That, says lead author Durand, is the subject of his current studies at the University of Witwatersrand in South Africa. He also wants to know how specific the benefit is: The kin-selection argument would be strengthened if the products of PCD are helpful only to members of the same species or strain.

The results aren't the first to suggest that suicide can aid neighboring cells. Related phenomena have turned up in ultraviolet-stressed *C. reinhardtii* and in aging yeast. But they are among the first to show a direct benefit to surviving cells and to compare the effects of different ways of dying. Frank Madeo, who studies PCD in yeast at the University of Graz in Austria, says the new study strengthens the idea that natural selection favors PCD because it helps the whole group of cells. "The overall story is nice," he says—although he wants to know more details about exactly how the beneficial effect works. He points out that an apparent boost in growth could actually be a decreased death rate in the culture.

At the same time, the new results leave intact several other hypotheses about the benefits of PCD. For instance, suicide could be an accidental by-product of some metabolic process—such as adapting to milder stresses—that makes cells competitive earlier in life. Or it may help algae combat viral infections. If virus-infected cells self-destruct before the pathogen can replicate, they spare their neighbors the infection. Bidle predicts all these factors are probably "part of the story" in every lineage of unicellular organisms.—*Elsa Youngsteadt*