the signs pointed to the equatorial Pacific. The decade-long pattern of altered circulation looked suspiciously like the far-flung atmospheric changes that often result from unusual heating of the eastern Pacific during an El Niño. The difference, of course, is that the pressure and circulation changes linked to an El Niño usually abate after a year or so, whereas the 1976 climate shift persisted year after year.

But this time, Trenberth pointed out, the warming of the El Niño region of the Pacific persisted as well. Three El Niño events warmed the tropical Pacific during the decade after 1976, but the other phase of the cycle—the cooler than normal episodes called La Niñas, which usually alternate with El Niños—was missing until 1988, when a strong La Niña apparently revived the full cycle of warm and cold swings. Until then, the heat never quite dissipated, and the extra heat in the tropics coincided with the regional climate change.

Still, coincidence does not prove causation, especially in meteorology. Now Nicholas Graham has firmed up that link with computer climate models, among them the most sophisticated sort in which the ocean and atmosphere interact on a global scale. By holding ocean temperatures constant except in the tropical Pacific, he was able to explore that area's effect on Northern Hemisphere climate. When he simulated the temperature changes of the tropical Pacific of the 1970s and 1980s, the model produced climate changes much like those seen after 1976. Short of having a dozen cases of such climate shifts to analyze, other researchers say, this sort of modeling is likely to be the strongest evidence available.

That's as far as climatologists have gotten in tracing the chain of cause and effect. Now they are left with a tougher question: What forced the basic change in the tropical Pacific? Speculations are scarce so far, and there's even some dispute about the nature of the post-1976 change itself. While Trenberth stresses the absence of the cold phase of the La Niña-El Niño oscillation, Graham thinks both phases continued, but the thermostat that determines background conditions was somehow reset to a higher temperature. Either way, surfers, citrus growers, and greenhouse policy makers would like to know if and when a shift is likely to happen again. ■ RICHARD A. KERR

ADDITIONAL READING

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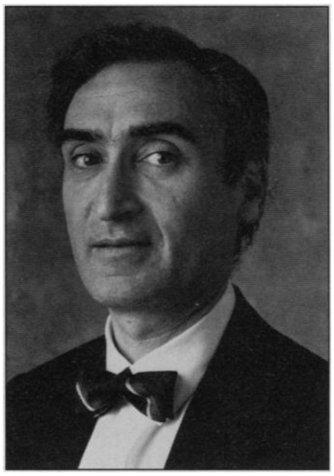
Yeast Biology Enters A Surprising New Phase

Baker's yeast is a well-known model for molecular genetics—but it wasn't quite so well known after all

MANY ANIMALS DON'T BEHAVE IN ZOOS QUITE the way they do in the wild. But the difference between an organism's captive behavior and its behavior in nature isn't limited to lions and tigers. Take *Saccharomyces cerevisiae,* otherwise known as baker's yeast, which in the past decade has become one of the favored model systems of molecular geneticists. While many related molds, such as the human pathogen *Candida albicans*, exist in two phases (a unicellular yeast and a multicellular filamentous phase), switching back and forth between them by an intricate genetic mechanism, *Saccharomyces* was believed to have only the unicellular yeast phase. Until now. In the 20 March issue of *Cell*, Gerald Fink and colleagues at the Whitehead Institute and the Massachusettes Institutes of Technology describe a filamentous phase in *Saccharomyces*.



Taken by surprise. *Gerald Fink at first doubted the evidence for a filamentous phase.*

"*Saccharomyces* had been domesticated by bakers and brewers over hundreds of years and it was thought that it had either lost the capacity to make the switch, or never had it," says Jef Boeke, a yeast geneticist at Johns Hopkins. Because the genetics of *Saccharomyces* have already been intensively studied, the finding could shed some fresh light on gene regulation—and it could ultimately have some clinical implications as well.

The notion of a filamentous phase in domesticated strains of *Saccharomyces* is so surprising that Fink himself says that at first he simply didn't believe the evidence that began to accumulate in his lab. "I thought it was a contaminant—a mold that had fallen in from the ventilation system. If you see it, it doesn't look like our guys," he says. But when graduate student Carlos Gimeno pointed out that the alleged contaminant could mate with the *Saccharomyces* cultures, Fink finally had to concede that they were one and the same.

How is it possible that a major portion of the life cycle has remained undescribed in an organism that is studied in hundreds of labs? The answer seems to be that in most lab cultures all essential nutrients are provided. And, as the new results from Fink's lab show, the filamentous phase in *Saccharomyces* is triggered by starvation.

The Whitehead group discovered this while exploring the environmental growth cues *Saccharomyces* responds to. They were, says Fink, "trying to turn the Petri dish into a facsimile of nature"—something like modern zoos, in which some animals are freed to roam in large open spaces that mimic their natural habitats. But, Fink notes, nature leaves yeasts like *Saccharomyces* in a state of semi-starvation. If it didn't, he explains, they would take over the world: "If you let just one cell divide at its maximal rate, it would form a layer around the earth 10 feet deep after just 2 weeks." Since that doesn't happen, there must be something limiting their growth.

To find out what the limits to growth might be, the group varied the amount of nitrogen in the cells' medium. Eliminating nitrogen completely, Fink notes, puts an end to growth, so they offered the cells reduced amounts of nitrogen. But they weren't quite prepared for what happened to their *Saccharomyces* cultures. Usually, when yeasts replicate, the daughter cell buds off from the parent and eventually forms an independent cell. But in a reduced nitrogen medium, the daughter cell remains attached to the tip of the mother. Then a new cell buds from that daughter's tip, and so forth, until it forms a filamentous chain of connected yeast cells. The *Saccharomyces* chain is actually able to invade the agar on which it grows, which individual yeast cells cannot do.

It is precisely this ability to penetrate agar that leads Fink to speculate that the filamentous phase is *Saccharomyces'* way of foraging for food. "The key thing is that these cells are not motile. So how can an immobile thing get to a new source of food?" he asks. In the filamentous phase, "these organisms can grow towards it," he says. The precise molecular mechanism of the switch awaits further study, but Fink and his colleagues have shown that they can induce the change of yeast lifestyle at will—simply by altering the nitrogen level in the cultures.

Fink isn't the only one who was bowled over by *Saccharomyces'* new phase. "The surprise is that a major developmental path had gone undiscovered in an organism so intensively studied by thousands. It is quite remarkable," says Boeke. Yeast expert Ira Herskowitz of the University of California, San Francisco, calls the discovery a "fascinating new piece of yeast biology that shows the relatedness of yeast and filamentous fungi."

And that relationship could make *Saccharomyces* an important medical model as well as a lab model for molecular genetics, since many of the fungi that cause disease in plants and animals have a filamentous phase. A typical example is *Candida albicans*, which causes vaginal infections, thrush, and often afflicts immunosupressed patients. In some cases, the filamentous phase is critical in allowing the pathogen to invade its host. And of all possible yeasts, *Saccharomyces* is best positioned to serve as a model, according to Fink, who notes, "The advantage here is that the genetics of *Saccharomyces* are so well worked out that the mechanism can be studied at the molecular level." And the elucidation of that model could provide yeast genetics with the beginning of an entirely new phase. ■ MICHELLE HOFFMAN

Making Light of Sound

ADRIENNE HELITZER

The light fantastic. *Seth Putterman* (right) *and Bradley Barber use ultrasound to coax light from liquid.*

Imagine concentrating all of the cheers from 20 million jammed stadiums, each packed with 50,000 spectators, into a brief but gargantuan shout from a single solitary fan. That might give you a feel for the phenomenon that has captivated Seth Putterman for the past 2 years. The more the University of California, Los Angeles (UCLA), physicist and his colleagues learn about the phenomenon, in which the energy of ultrasound beamed into a liquid is apparently concentrated a trillion-fold to produce fleeting flashes of light, the stranger it gets.

Putterman's latest measurements of these light pulses "knock my socks off," remarks University of Illinois sonochemist Ken Suslick. The measurements, which Putterman and his UCLA colleagues Robert Hiller and Bradley Barber reported this week at the American Physical Society (APS) meeting in Indianapolis, suggest that the light pulses last just trillionths of a second. That's hundreds of times faster than experts in the physics of fluids can explain by standard theories.

The basic phenomenon, called sonoluminescence, was first reported 58 years ago by German scientists. Having noted the sound-to-light conversion, though, they didn't pursue it, says Putterman. "They thought it was boring." Since then, other researchers tried developing a rough explanation for the light emission. They've proposed that the tiny gas-filled bubbles created by the ultrasound collapse violently, spurring energetic molecular fragments within the bubbles to perform light-emitting slam-dances. For years, sonochemists like Suslick have been exploiting the violent conditions of the bubbles to drive chemical reactions and to make new materials. But the erratic, flash-in-the-night nature of sonoluminescence hampered physicists' efforts to nail down the mechanisms of light production.

By the end of the 1980s, physicists were gaining tighter control over the brilliant bubbles, opening the way to more precise measurements of their workings. The key development came from Lawrence Crum of the University of Mississippi and Felipe Gaitan, now at the Naval Postgraduate School in Monterey, who varied the viscosity of their liquids and the frequency of the ultrasound until they had a single, tiny bubble emerging, expanding, and contracting at the frequency of the ultrasound, all the while emitting light. "You can see it with your naked eye," Crum notes.

The two reported their work at a conference in 1989, "but nobody thought it was extraordinary," says Crum. Nobody, that is, until Putterman entered the sonoluminescence picture about a year later. He had begun looking into the phenomenon following a cafe conversation with physicist Tom Erber of the Illinois Institute of Technology. Erber, then a visiting professor at UCLA, had challenged Putterman, who had a longstanding interest in fluid mechanics, to figure out how in the world "do you get light out of sound."

Back of the envelope calculations indicated that for the diffuse energy of sound to excite light-emitting electrons in the fluid, it has to be concentrated by a whopping 12 orders of magnitude. "I immediately saw that this is amazing," Putterman says. To get a sense of what physical mechanisms might be at work, one of the first things he wanted to do was measure the length of the flashes. He set Barber the task of modifying their own experimental efforts à la Crum and Gaitan. Using what Putterman believes are the world's fastest photo multiplier tubes, the UCLA workers recorded a clockwork sequence of pulses lasting less than 50 trillionths of a second each. Says Putterman, "This is shocking to us."

It's shocking to other researchers in fluid mechanics, too. Andrea Prosperetti, a fluid mechanics expert at Johns Hopkins University, has tried and, so far, failed to find a way of explaining how energized molecules in the bubbles could produce flashes shorter than a few nanoseconds—hundreds of times longer than the pulses measured by the UCLA workers. "I can't make it work," says Prosperetti. And that is leading him to say reluctantly that some brand of new physics "seems a little more possible" as an explanation for the phenomenon.

Other measurements the UCLA group reported at the APS meeting have only deepened the mystery. By recording a spectrum of the emitted light, the researchers found it didn't tail off even at high-energy, ultraviolet wavelengths. That leads Putterman and his colleagues to think the bubbles may also be emitting at even shorter, more energetic wavelengths that went undetected because they are absorbed by the liquid.

If so, any theory of sonoluminescence may have to explain an energy amplification even higher than had been thought. But once such a theory is in hand, says Putterman, scientists may be able to exploit the process to pull off even more dramatic feats of energy focusing, an ability that could prove useful in both basic and applied research. ■ IVAN AMATO