EVOLUTION

Biodiversity in a Vial of Sugar Water

ARNHEM, THE NETHERLANDS—Most biologists head into the field to test hypotheses about the processes that generate biodiversity. But for a few researchers, the insights are coming from trips to the lab. At the recent meeting of the European Society for Evolutionary Biology here, researchers described how microbes living in a vial full of nutrient broth can form a rainforest in miniature, quickly diversifying into a range of new forms.

The diversity is nothing like the dizzying array of forms that emerged from, say, the Cambrian explosion half a billion years ago, notes Paul Rainey of Oxford University, who did the work with his colleague Michael Travisano. But "it nevertheless bears some of the hallmarks of such macroevolutionary events," he says. And that means evolutionary biologists can study these miniature adaptive radiations for clues to what drives them in nature. Rainey and Travisano "have devised this fantastic, apparently repeatable experiment that shows exactly how it happens," notes Andrew Read, an evolutionary biologist at the University of Edinburgh in the United Kingdom. "It's bound to become a classic."

Rainey and Travisano staged their demonstration by placing *Pseudomonas fluorescens*, a common aerobic bacterium that thrives in the soil as well as on plants, in an unfamiliar habitat: a broth-filled vial. The vial, says Rainey, "offers a variety of environments, all differing in the amount of available oxygen," which varies with depth in the broth. Five days later, the original ancestor, which the researchers dubbed the "Smooth Morph" (SM) because its colony has a smooth surface, had undergone rapid morphological change, giving rise to numerous new forms, each one presumably adapted to a specific niche in the vial. In its small way, the vial thus mirrored Earth's seas "after a major extinction event," says Rainey. "The bacteria had lots of opportunity for diversifying, and bang!, they just went."

As long as the vial sat undisturbed, that microbial diversity was maintained. But when Rainey shook the tube, he destroyed the structure of the bacterial colonies and the variations in oxygen. The multiple niches vanished—and so did the accompanying diversity. Rainey let the vial sit again, and within a week's time, the diversity reappeared.

To show that good, old-fashioned natural selection was driving this diversification, the researchers first set out to identify the specific habitats of two of the most common morphs. On their own, these formed distinctive colonies. One grew a wrinkly, sticky surface (which the duo labeled "Wrinkly Spreader," or WS), and one looked like a dust ball (the "Fuzzy Spreader," or FS). The team then placed a few cells from these colonies as well as from the ancestral (SM) stock in a pristine vial environment, where their habitats would be easier to identify than in the original, more complex ecosystem.

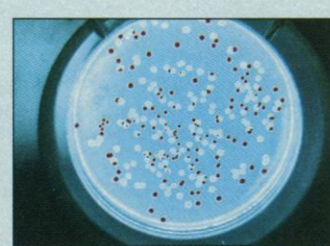
Within 3 days, WS had colonized the broth's surface, forming a thick mat; FS had settled in at the vial's bottom; and the ancestral SM was thriving in the middle. To further establish that the morphs had adapted to distinctive habitats, the team set them against each other in mano a mano competitions. For instance, they placed 100 cells of WS into a vial with a single cell of SM, and vice versa. In all cases, the minority cell survived and multiplied. "That could only happen if each morph [had adapted to occupy] a separate niche; otherwise, the rare form would go extinct," says Rainey.

"It's a very exciting experiment," says Richard Lenski, an evolutionary geneticist at Michigan State University in East Lansing. "Other people have shown the complexity and rapidity of evolution, but [Rainey's team] is demonstrating that all together in one experiment—as well as showing the importance of natural selection."

–Virginia Morell

Natural Selection's Capricious Ways

New habitats are sure to produce a gamut of new adaptations, as test tube experiments show (see main text). But predicting just how an organism will respond to a new environment can be dicey, Michael Travisano, an evolutionary biologist at Oxford University, has shown in another evolution-in-miniature project.



PACO MOORE

Microbes, mano a mano. Two strains, one with red marker spots, compete on a growth medium.

Travisano studied 12 populations of *Escherichia coli* bacteria that have spent 10 years living on a low-sugar diet in Richard Lenski's lab at Michigan State University in East Lansing. To see how these populations had adapted to their meager diet, Travisano grew the glucose-adapted microbes in 11 new, slightly different environments: broths containing other sugars, such as lactose, fructose, and melibiose. After only 1 day, he measured their fitness by counting the number of descendants they had produced in that short amount of time. The numbers varied wildly, as the microbes thrived on some sugars, while stumbling badly on others.

E. coli normally fares well on all of these sugars, so the varying responses suggested that the glucose-adapted microbes had undergone some physiological change, Travisano says. He suspects that Lenski's original strain adapted to living on a low-glucose diet by improving specific uptake mechanisms for glucose, which would enable the bacteria to digest the sugar more efficiently. Those mechanisms "preadapt" the bacteria to thrive on glucose-like sugars, such as fructose. But place them in a different sugar, such as melibiose, and the glucose-evolved bacteria falter.

Yet the uptake mechanisms apparently did not change in the same way in all 12 strains, because the pattern of fitness they showed on the new sugars differed from strain to strain. "Travisano has put identical individuals through the same selection regime—and come out with greatly varying responses," notes Peg Riley, an evolutionary biologist at Yale University. In other words, faced with one evolutionary pressure—in this case, a low-sugar environment—an organism can evolve several different solutions to improve its fitness.

Travisano also let bacteria from Lenski's original *E. coli* ancestor evolve for 1000 generations on a restricted maltose diet instead of glucose. He then switched the maltose-evolved microbes to glucose, where they continued to thrive. "That might lead you to predict that the reverse is true, too," he says: "that glucose-evolved bacteria will do well in maltose." In fact, they vary greatly in their response, with some improving, others becoming substantially worse, and others not changing at all—a finding that underscores the different ways in which the glucose-evolved microbes had adapted to the same environment.

Concludes Paul Rainey, Travisano's colleague: "Predicting the outcome of adaptive evolution is a risky business." –V. M.