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After 50,000 generations, bacteria are still evolving greater fitness

The more mutations, the faster they get fit.

by John Timmer - Nov 17 2013, 3:00pm EST

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Not quite this kind of fitness...

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experiment is still going. Lenski has watched the bacteria evolve to compensate for the stresses of harsh culture conditions, and he's been able to track the exact changes that allow them to do so. In the process, Lenski's learned a few things about the nature of evolution itself.

In his latest progress report on the bacteria, the lab set up a competition, pitting bacteria that had been adapting for different periods of time against each other. He found that those at the 50,000 generation mark not only beat the ones at 10,000 generations, but these bacteria also come out ahead of the ones at 40,000. The continual improvements suggest that, when it comes to fitness, these bacteria are nowhere close to reaching a point where improvement levels off.

Lenski's basic approach to evolution involves being cruel to *E. coli*. The organism evolved to survive in the rich environment of our guts and, for many generations, it has all its nutritional needs seen to by the media scientists provide it. Lenski put them on a starvation diet, with only enough glucose to get them through a few cell divisions. After that, the cells had to either come up with a different energy source or sit around and wait until the food was changed the next day. Every 500 generations, a sample from each of the dozen cultures was frozen, preserving the bacteria like a time capsule.

Over the years, evolution has radically altered the bacteria. Some but not all the cultures **evolved the**



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ability to use citrate instead of glucose, leading to a significant growth advantage. Others picked up genetic changes that left them more susceptible to mutations, accelerating their ability to adapt. But these mutations took place tens of thousands of generations ago. Lenski decided to see if evolution was still driving increases in fitness, or if the bacteria had already achieved all the improvements they were likely to see.

To see if the tests were worthwhile, the researchers took the current group of bacteria (about 50,000 generations into the experiment) and compared them to some samples saved from generation 40,000. When competing for growth against each other in the same medium, generation 50K grew faster in nine of the 12 cultures, and it was roughly equal in the rest. To get a full fitness curve, Lenski's group then set all 12 cultures into competitions with their own pasts, using as many as 40 competitions for each culture.

The end results for all cases were pretty clear: the bacteria made large gains in fitness during the first few thousand generations, after which the pace slowed. But the increase in fitness never really stopped. The fitness curves were tested to see if it looked like a hyperbola, which approaches but never exceeds a fitness limit, or a power law, in which case fitness will continue to increase over time even as its pace slows. The results were pretty clear: "the power law outperforms the hyperbolic model with a posterior odds ratio of ~30 million."

The team then attempted to build a mathematical model that would describe the fitness increases based on the mutation rate. One of the notable features of their model is that it left out the occurrence of harmful mutations entirely, and it still produced accurate fits to the fitness curves. In other words, evolution seems to be so efficient at getting rid of harmful mutations that they can safely be ignored.

Another way this became apparent is the hypermutator strains. Half of the original dozen strains picked up mutations in genes that resulted in further mutations accumulating at a 100-fold higher pace. If negative mutations were much of a problem, then the hypermutators should show fitness curves that were below those of the remaining strains. Instead, they achieved higher levels of fitness than their peers by 10,000 generations and continued to stay ahead for over 40,000 generations.

This isn't to say that there won't come a choice where a higher mutation rate will become a problem. But it's clear that, while adapting to a radically different environment, it's a significant benefit.

The authors note that the bacteria have one thing going against them: they don't have sex. It's entirely possible that some helpful mutations occurred in these populations that were simply outcompeted by things that made an even larger improvement in fitness. Had the population been exchanging genes, it would have been possible to get both mutations into the same organism.

Finally, the authors note that there's no indication of things slowing down. In fact, they point out that many adaptive mutations also cause some minor negative side effects. Further evolution can undo the negatives, increasing the fitness of the population even further.

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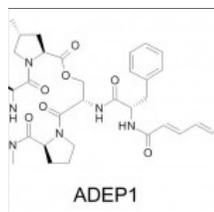
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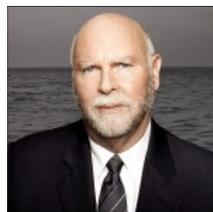
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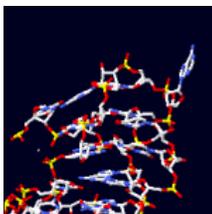


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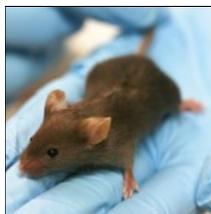
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