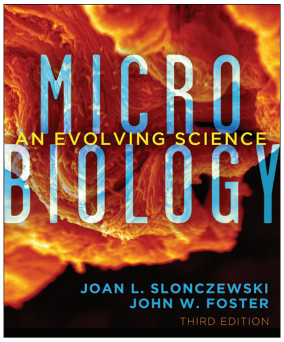

MICROBIOLOGY

AN EVOLVING SCIENCE, THIRD EDTION

Joan L. Slonczewski, Kenyon College • **John W. Foster,** University of South Alabama

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COURTESY OF RICHARD LENSKI

Richard Lenski, Hannah Distinguished Professor, Michigan State University.

AN INTERVIEW WITH:

Richard Lenski

Evolution in the Lab

Richard Lenski, an evolutionary biologist, has taught for over 20 years as the John Hannah Distinguished Professor at Michigan State University. Since 1988, Lenski and his students have been tracking phenotypic and genetic changes in 12 initially identical populations of bacteria. Their report of *E. coli* bacteria evolving a new trait in the laboratory earned headlines from the *New York Times* and other media around the world. Lenski cofounded BEACON, the National Science Foundation's Center for the Study of Evolution in Action.

How did you decide to make a career in microbial evolution?

I got interested in biology as an undergrad at Oberlin College, and I was especially fascinated by ecology because there were so many unanswered questions. So I went to grad school at the University of North Carolina to study ecology. I began to see the deep connections between ecology and evolution. Many ecologists have lifelong interests in particular organisms—birds, snakes, butterflies, or whatever. But I didn't have any special skills in that respect; I was more interested in the general questions. I remembered the elegance of the genetics experiments with bacteria that I had learned about as an undergraduate. So I decided that, for my postdoctoral work, I should find a lab where I could learn how to work with microbes. I found a superb mentor, Bruce Levin, who was interested in evolution.

Why did you perform your long-term experimental evolution study with *Escherichia coli*? What makes it different from previous studies of evolution?

I started the experiment to ask one main question: How repeatable is evolution? Mutations occur at random, but populations become more fit over time if some of the mutants survive and reproduce better than their ancestors—that's natural selection. In essence, I wanted to know how many different ways there were for the bacteria to adapt to a particular environment.

I set up 12 populations, all started from the same *E. coli* strain, and each one in an identical flask containing a medium where glucose is the source of energy. Every day, someone takes 1% of the volume from each flask and transfers it to a new flask with fresh medium. The bacteria grow and, after some hours, deplete the glucose, so it's a "feast or famine" existence. The dilution and regrowth allows about seven bacterial generations per day. I started the experiment in 1988, and the bacteria have now been evolving for well over 50,000 generations. So many interesting things have happened that I've kept it going all these years. In fact, I hope the experiment will continue even after I'm gone.

This project differs from most research on evolution because we're watching evolution in action. Most evolutionary biologists study fossils or use the comparative approach—that is, quantifying similarities and differences in phenotypes and genomes of living organisms—in order to infer the characteristics of organisms that lived in the past. In this *E. coli* experiment, we can observe changes as the generations go by, and we can directly

COURTESY OF RICHARD LENSKI

One *E. coli* population evolved the novel capacity to consume citrate for energy (clouded flask).

compare the evolving bacteria with their ancestors. We've stored the ancestral strain and samples from every 500 generations in a freezer, and with *E. coli* we can revive the frozen cells. It's like bringing fossils back to life.

Over the 25 years of this experiment, the research has involved dozens of dedicated people. I have an excellent technician, Neerja Hajela, who either does the transfers herself or makes sure someone else does them. Mike Travisano was the first student to base his dissertation research on this experiment, and he's now a professor at the University of Minnesota.

What results have you obtained? Have any results surprised you?

One result is that the average fitness in each population increases over time. We measure fitness by competing bacteria from different generations against the common ancestor. This result is not surprising, since the environment has been constant over time, but it's a concrete demonstration of adaptation by natural selection, the same process that Darwin discovered.

Another finding is that evolution can be quite repeatable; that is, we've seen many examples of parallel changes in the replicate lines. For example, all 12 populations evolved to produce larger individual cells than the ancestor produced. And when we look at their mutations, we see many cases in which some or even all of the lines have mutations in the same genes.

The most dramatic change we've seen happened in only one population. Glucose was the source of energy for the bacteria, but there's been another resource—citrate—in the medium all along. *E. coli* cells can't use the citrate, however, because they're unable to take up citrate in the presence of oxygen. In fact, the inability to grow on citrate is a key feature of *E. coli* as a species. But after about 30,000 generations, a mutant in one population discovered there was something else to eat besides the glucose. At first I thought we had a contaminant—some other species—in this flask, but genetic analyses showed it really was a descendant of the *E. coli* strain used to start the experiment. So here's a case where one population evolved to be very different from all the other populations. Zack Blount, a postdoc in the lab, is analyzing the mutations that allow the bacteria to grow on citrate. Caroline Turner, a grad student, is studying how this new ability changes the ecological interactions between different genotypes in the population.

What new technologies have made it possible to take full advantage of your study?

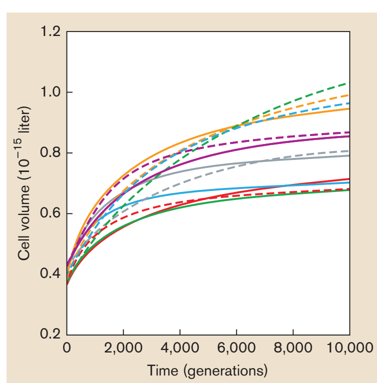
When I started this experiment in 1988, I couldn't imagine the amazing technologies that would come along and allow us to analyze the evolution that has taken place. The ability to sequence entire genomes is the most important advance. By sequencing the genomes of evolved bacteria and comparing them to the ancestor's genome, we're finding the mutations that led to improved fitness and other phenotypic changes.

Does experimental evolution have industrial applications?

Yes, it does. Humans can apply evolution for practical purposes, just like we use other natural processes, such as gravity and the action of water, to do work via mill wheels and hydroelectric plants. In fact, the selective breeding and domestication of farm animals, crop plants, and even microbes (like baker's yeast) show that our ancestors employed evolution for practical purposes long before the mechanisms of evolution were understood. More recently, scientists have been pursuing genetic engineering to modify microbes for new purposes, like biofuels. Experimental evolution—where scientists construct environments that select for organisms with the desired properties—offers a valuable complement to genetic engineering.

How does your family relate to your work?

I sometimes joke that I have two families: my biological family with my wife and kids, and my lab family, with all the students and postdocs who've been a part of it over the years. As much as I love my work—and I can't imagine a better job than being a biology professor—there's always more research to be done. So I'm grateful that my wife and kids have been supportive of my work. Now I have a granddaughter, and she reminds me just how fortunate I am to see another generation in the great evolutionary tree of life.



Cell size increased in all 12 evolving populations of bacteria. *Source:* Modified from Richard Lenski and Michael Travisano. Dynamics of adaptation and diversification: a 10,000-generation experiment with bacterial populations. 1994. *PNAS* **91**:6808.

For further details on Lenski's experimental evolution of *E. coli*, see Chapter 17 Origins and Evolutions.