Evolution: Scientists Grow 56,000 Generations in Lab to Watch

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Scientists Grow E. Coli Bacteria in Lab for 25 Years to Watch Mutations

Wouldn't it be great if scientists could climb into a time machine and travel back in history to observe thousands of generations of a single living creature to see how it evolved over many years?

It turns out they've done just that, and they returned with evidence that the evolution of life is far more complex than many had thought. Instead of a single mutation that gave the creature an advantage over its peers, it took several mutations, in a very precise order, for the creature to be able to digest something it could not have eaten before.

The result? The "creature," in this case, is Escherichia coli, a common bacteria found in the guts of most mammals, and its population exploded because of its new diet.

"They are doing something E. coli is not supposed to be able to do," Zachary Blount, a postdoctoral researcher at Michigan State University and lead author of a study in the current issue of the journal Nature, said in a telephone interview.

One of the distinguishing characteristics of the bacteria is its inability to eat citrate (a very common salt compound) in the presence of oxygen, but that old rule has now been broken. It's all part of a remarkable story that has been unfolding for 24 years in Michigan State's Beacon Center for the Study of Evolution in Action.

It's difficult to study evolution in real time because it requires many generations to document evolutionary changes, so scientists have been forced to turn to animals that reproduce quickly, like flies and bacteria.

In 1988, Richard Lenski, a professor of microbiology and molecular genetics at Michigan State, launched a research project that is believed to be the longest running evolution experiment in history, at least in terms of generations. Twelve populations of E coli live in an incubator in Lenski's lab, and they produce about seven new generations every 24 hours.

So over the last 24 years, Lenski and his colleagues have studied the bacteria through more than 56,000 generations. Samples are taken and frozen periodically, providing a fossil record all the way back to when Lenski started out with a single ancestor.

"Freezing doesn't kill bacteria, like it does humans or zebras," Blount said. "We can thaw them out and put them in a growth medium and grow the bacteria up again."

That provides a record of evolutionary changes back to the beginning of the experiment, and a few years ago, Lenski's team discovered something odd.

At about generation 33,000, the bacteria in one of the 12 populations had started eating citrate in addition to its normal diet of glucose. Citrate, which was in the medium to help the bacteria absorb iron, is a no-no for E coli, and that left the scientists curious. How had that happened?

By checking the frozen fossil record, Blount and his colleagues were able to piece together exactly when various mutations occurred, and that turned into quite a story.

An early mutation, about generation 31,000, "set the stage," Blount said, raising the potential of adding citrate to the bacteria's lunch menu. But it took a couple thousand more generations for E coli actually to begin "nibbling" at the citrate. And finally, after at least one more mutation, it started "wolfing" it down.

That additional nutrient gave that single population a substantial edge over the other 11 colonies, as evidenced by the enormous growth of the citrate eaters.

"Zack showed you could re-evolve the citrate-eaters, but only after some of the other pieces of the puzzle were in place," Lenski said.

Some 29 genome sequences for the bacteria were carried out by the researchers, allowing them to pinpoint exactly when the various mutations occurred. Mutations were not unexpected, Blount said, because "they are going to occur as a matter of course because DNA replication is not completely accurate and that introduces some errors."

That's the way it happens throughout nature, not just among bacteria. With the exception of such things as chemical assaults and radiation, nature doesn't drive evolution. It's the other way around.

Mutations occur randomly, and usually do more harm than good, but occasionally they turn out to be beneficial to the organism. When it's beneficial, the organism will likely "select" the mutation and add it to its arsenal.

That's precisely what happened to the bacteria, although it took several mutations -- one to kick-start the process, another to get the ball rolling, and a third to take full advantage of the opportunity.

"These bacteria have evolved to consume a food resource -- citrate -- that no wild E. coli uses," said George Gilchrist, the National Science Foundation's program manager for the Michigan State project. "Three mutations (at least) were required for this to happen, and they must occur in a specific order."

He went on to say that the research suggests "complex traits, at least in the microbial world, can evolve quickly and repeatedly."

That still leaves at least one question dangling. Is the citrate-eating bacterium a new species? That's Blount's next challenge. And it won't be easy either.

"The question of what is or is not a species is a tangled one," he said. There literally are over 100 different species definitions."

But since the citrate eaters are doing something their kinfolk can't do, maybe they are a new species.

"This may be a chance to watch a new species forming from the very beginning," Blount said.