Experiments That Keep Going And Going And Going

by NELL GREENFIELDBOYCE

Enlarge Michigan State University

William Beal, standing at center, started a long-term study on seed germination in 1879. He buried 20 bottles with seeds in them for later researchers to unearth and plant.

November 23, 2012

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A biologist who has been watching a dozen bottles of bacteria evolve for nearly a quarter of a century is hoping he can find someone to keep his lab experiment going long after he dies.

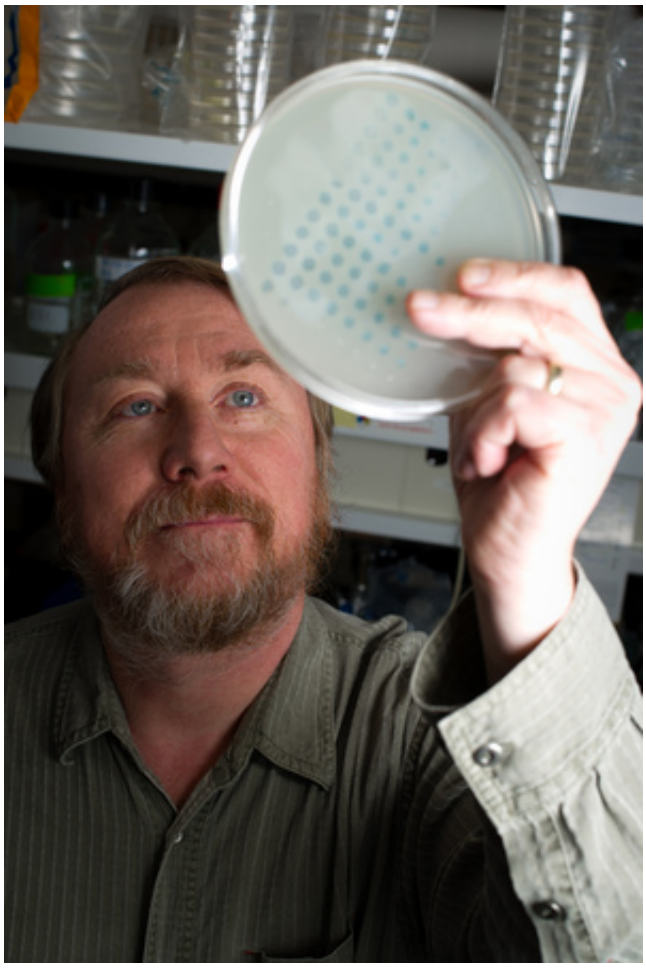
Meanwhile, just by coincidence, a botanist who works across campus is carefully tending an experiment that started before he was born, all the way back in 1879.

These two researchers, both at Michigan State University in East Lansing, represent different sides of an unusual phenomenon in science: experiments that outlive the people who started them.

Most researchers design studies to churn out results as quickly as possible. But

because nature can work on vast time scales, some questions can take longer to answer than any one scientist's career.

Richard Lenski began his evolution experiment in 1988 with a simple question: Does evolution always lead to the same end point? If he started with 12 identical flasks, full of identical bacteria, would they all change over time in the same way? Or would random mutations send each bottle's population spinning off in a different direction?



Enlarge G.L. Kohuth/Michigan State University

Richard Lenski examines the growth of bacteria on a plate on Jan. 12. He began an evolution experiment in 1988 with 12 identical flasks of bacteria to see if the populations would change over time in the same way.

"This was an experiment that was intended to be a long-term experiment, although I had no idea that it would be multiple decades," says Lenski, an evolutionary biologist. "It does just keep producing new and interesting results, so it doesn't seem to be near the end of its life span."

Every day, someone in his lab has to do the brief, tedious chore of feeding and caring for the bacteria. On day number 8,449, Lenski reached into an incubator and pulled out his old friends.

These *E. coli* bacteria reproduce so rapidly that, in one day, they speed through seven generations — creating the equivalent of their great-great-great-great grandchildren and letting Lenski watch their evolution in real time.

Lenski brought the flasks over to a lab bench and reached for his glasses. "When I started this experiment, I didn't need reading glasses," he notes, "and now looking at things close-up is always more work than it used to be."

For the first decade of his experiment, the bacteria in each flask mostly changed in similar ways. For example, they all were producing larger cells.

Then things got kind of boring for a while because the changes started coming more slowly. Lenski had other projects going on in his lab, and figured that maybe he'd learned all he could from this one.

"And so I was sort of thinking, 'OK, maybe it's time to stop the experiment,' " he says, recalling that he asked a few colleagues what they thought of that idea. "And they basically said, 'Nope, you can't stop it, it's gone on too long.' "

So he stuck with it. And a few years later, in 2003, something happened. The liquid in one flask looked strange. "This flask was considerably more cloudy," says Lenski. "I was suspicious that we had a contaminant."

It turns out that the bacteria in that one flask had actually changed in a dramatic way. After 30,000 generations, they had suddenly gained the ability to consume citrate, a chemical that had always been in the flasks — but that was never intended to be a food, since laboratory *E. coli* normally can't eat it.

What's more, Lenski was able to trace exactly how that new trait emerged. Over the years, he's been freezing samples of his bacteria, so he was able to go back and track every little genetic change that's taken place through the generations, using technologies that didn't even exist when he first started this study.

Lenski is now convinced that this study should keep going far into the future, to see what else might evolve. He'd like to see this experiment go on not just for 50,000 bacterial generations but 50,000 human generations, to "really get some very hard numbers on the process of evolution."

The fact that Lenski won't be around to see those hard numbers doesn't seem to bother him.

"My wife and I were very fortunate that one of our daughters had a baby about 20 months ago. And that really changes one's perception of time even more than a long-term experiment," Lenski says.

He notes that people tend to conflate the universe with their own existence, "but having children, grandchildren and so on ... you really just come to grips with the vast span of time that is available. And we only get to occupy a tiny portion of it."

Lenski, who is 56 years old, thinks he'll watch his bacteria for about another

decade. Then he'll have to find someone to inherit this project. It's not a particularly expensive or difficult study — so he just needs to find someone younger who has a lab and is willing to carry his vision forward.

"They might be in their, you know, early- or mid-30s or something like that," Lenski says, "and then they can decide whether they want to do it for just the next five or 10 years or whether they want to continue it for another 30 years and perhaps pass it on to somebody who hasn't even been born yet."

Is it really possible to keep an experiment going like that? The answer is undoubtedly yes, as Lenski learned years ago when he heard of another long-term study happening on campus.

"Here I was, proud of myself for what was at that time maybe a 15-year experiment, discovering that it wasn't even the oldest experiment on campus — that there was another one up around 100 years, or even past that," recalls Lenski.

Seeds Buried Long, Long Ago

That experiment is currently cared for by Frank Telewski, who runs Michigan State University's botanical garden. The garden is named after botanist William J. Beal, and he started a long-term study on seed germination all the way back in 1879.

Beal was inspired by local farmers who had been asking him this question: If we weed our fields year after year, will we ever reach a point where the weeds just don't come back?

"Well, that was a very interesting question," says Telewski, because it wasn't at all clear how long seeds might remain viable in the soil. "We know that seeds can remain dormant for a long period of time, and Professor Beal's key question was, 'How long?' "

So Beal put a precise quantity of seeds from different species into 20 sand-filled bottles and stashed them underground. The original plan was to dig up one bottle every five years and see what would grow.

Enlarge Kurt Stepnitz/Michigan State University

Bottles like this 90-year-old one were filled with seeds and sand, then buried by William Beal. Researchers periodically unearth a bottle and plant the seeds to see if they grow.

"Clearly, burying 20 bottles and only taking one out every five years, the plan was to go beyond Professor Beal's career, let alone Professor Beal's life," says Telewski.

The only writings from Beal about his experiment are dry scientific reports, but Telewski assumes it meant a lot to him.

"He had to be passionate about it," says Telewski. "You don't do something like this, you know, with that long-term desire, without being passionate."

Beal opened six bottles before he retired. Then he passed it on to a colleague, Henry Darlington. Eventually it was taken over by others, including Robert Bandurski and Jan Zeevaart, who passed it on to Telewski.

The experiment has lasted longer than Beal ever intended because the caretakers extended it. They first decided to open a bottle only once every decade, and now, once every two decades.

Telewski dug up his first bottle 12 years ago. He did it at night, with a flashlight, trying not to draw any attention to the secret burial spot. He says it was exciting to think back and remember that the last person to see the seed was Beal, 120 years ago. "For me that holds a level of significance, that holds a level of fascination, charm," says Telewski.

And he says the mysteries of long-term seed viability remain scientifically interesting. Only two plant species sprouted from the last Beal bottle. Telewski can't wait to dig up the next bottle, in 2020.

Will that be the year that nothing germinates, wonders Telewski, or "will something that hasn't germinated in 30, 40 years all of a sudden appear?"

This kind of inherited experiment is unusual, says Telewski, but in another way, the whole of science is one big long-term effort. Every time researchers record a careful observation, or stash a specimen in a museum, they make it possible for some unknown person of the future to pick up where they left off.

"And isn't that wonderful that somebody, somewhere, thought forward enough to

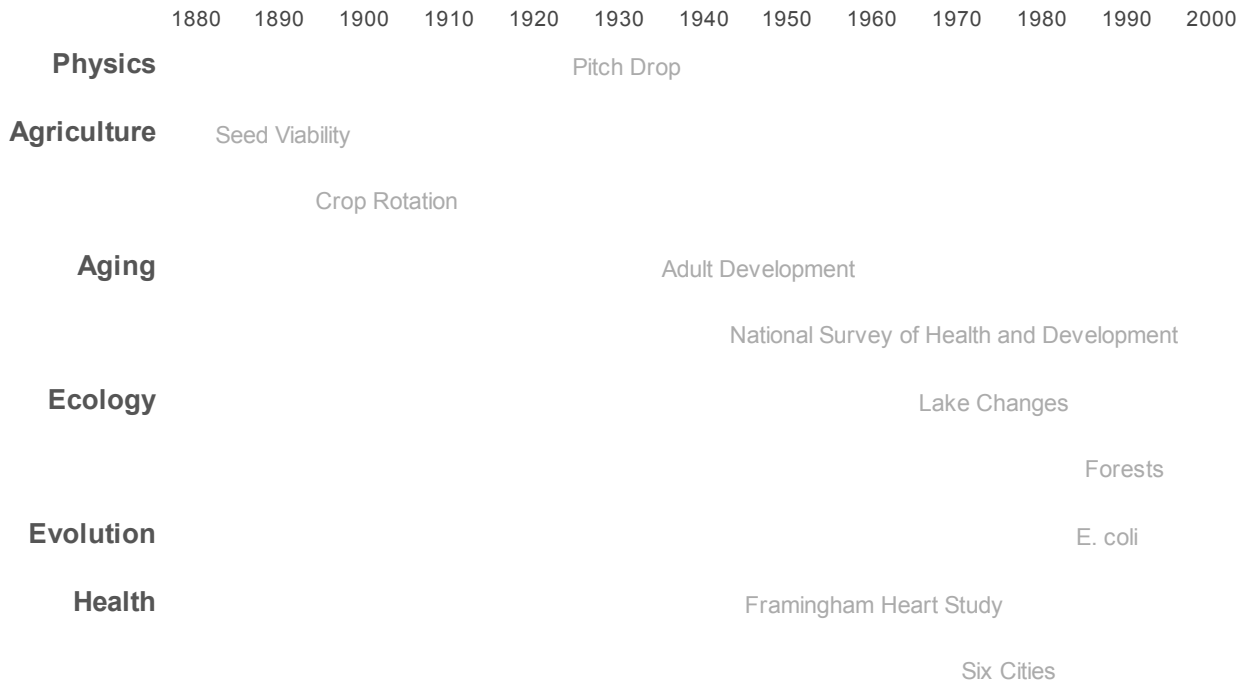
say, 'Let's hold onto this, let's keep this experiment going, let's design this experiment to go on and see where it takes us,' " says Telewski.

Telewski already has someone in mind to inherit the Beal study when he retires. "There's one particular person I've been speaking with, and I think she's going to be very excited to pick it up," he says.

If all goes as planned, he thinks the experiment will probably outlive her, too.

Long-Term Science Experiments

Some research studies don't yield quick results, and scientists design experiments that continue for years, if not decades. Below is a sampling of some long-term projects, many of which continue to this day. *(Mouse over the bars for more information about each study.)*



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don thayer • 3 days ago

Excellent incite into the scientific process. Thank you!

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Richard Spinner • 3 days ago

Science is difficult. These results are interesting. Imagine, 30,000 generations to detect one change. The implications could be profound.

Good story. Very insightful.

22 • Share ›

Bob H → Richard Spinner • 2 days ago

"The implications could be profound."

No "could be" about it. They ARE profound. Just read about the similarity of human and chimp DNA sequences and the apparently fairly minor evolutionary changes that have given us our human intelligence and all that derives from it.

Interesting that using 25 years per human generation, Lenski's 30k generations for E. coli translates to 750k years, which is within in the range of the estimated divergence of modern humans from Neanderthals (http://dienekes.blogspot.com/2....

17 • Share ›

Richard Spinner → Bob H • 2 days ago

I'm not a scientist but once studied biology. One of my undergraduate professors studied intertidal diversity. He observed an interesting distribution between two species of barnacles in the tidal zone. His observation lead to the first direct evidence of competition in nature. No small accomplishment.

In graduate school, I studied microbiology. I was still fascinated by interspecies competition. I had an idea to study competition by varying environmental conditions (nutrients, temperature, pH) for two species of bacteria over time and see what happened. I spent a good six months at it and started to get some interesting results but I discovered I liked coeds, parties, and surfing more than lonely hours in the lab.

When I read a story (and this was a pretty good one) about the steadfast determination of scientists like Dr. Lenski constructing an experiment very similar in structure to my own and staying with it to achieve that one discovery that I failed to do, I scatch my head but have to tip my hat to him.

Science is hard work and persistence!

6 • Share ›

Richard Spinner → Bob H • 2 days ago

Not quite the same. Human evolution takes place at a much faster

Not quite the same. Human evolution takes place at a much faster generational rate than bacteria because sexual recombination accelerates genetic variability. Sexual recombination compensates for our much longer generation time.

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Tim Bruce • 3 days ago

I love MSU! Go Green, Go White!

And go science! These kind of experiments fill me with the wonder of science I had as a child...

10 • Share ›

Justa Nuthabein • 2 days ago

the commitment to the persistence of knowledge that exceeds the awareness of one`s own mortality is one of the few characteristics of our species that lead me to hope for our continued survival, even as we threaten that very survival with our incessant denial of the long term consequences of some of our short-term "advantages."

7 • Share ›

Anne Hochberg • 2 days ago

Another long experiment is in Yosemite National Park, where Joseph Grinnell meticulously tracked animals over 100 years ago. In 1910, he had the foresight to predict that the real value of his and his colleagues' painstaking fieldwork would not "be realized until the lapse of many years, possibly a century." He already saw changes afoot in his time, and hoped that future scientists would return to his study sites and chart the changes. They have.

2003 was the first year of a resurvey of the "Yosemite Transect"; I am not sure whether it is still in progress or not. Jim Patton is one of the researchers. Much has been discovered about the changes in habitat of almost all of the local fauna. Most had migrated to higher locales (suggesting effects of a warmer climate).

More information can be found in an article called "The Ghosts of Yosemite" by Michelle Nijhuis, published in High Country News (perhaps in March 2008? The reference is www.hcn.org/issues/308/15837/p....

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Doc James • 3 days ago

This makes me feel kind of shallow. At one time, I lamented about spending 18 months on one project in grad school. My other doctoral projects took about a year each, which seemed about right at the time.

I'm not sure what I'd prefer, though: faster or more interesting.

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Joe Real • 2 days ago

We have been doing one giant unrepeatable experiment with our atmosphere. Many unnatural proprietary chemicals would take hundreds of thousands if not millions of years for our planet's ecosystem to equilibriate. Our EPA testing of manmade unnatural chemicals is only at most 3 years while the side effects are still felt for several generations. The DDT for example has never ending consequences that has permeated our planet's entire biota. Loading our atmosphere unabated, and our surroundings with various unnatural chemicals are runaway experiments that will be with us forever. Yet, the author have not mentioned any of these more pressing very unpleasant issues.

5 1 • Share ›

Barak Buttbama → Joe Real • a day ago

Well, hopefully, all those unnatural chemicals will exterminate the pestilence that is mankind. Earth would be better off.

0 • Share ›

Phil Firestar • 2 days ago

Great article! This goes to show that time and diversity offer an incredible amount of dimension. Ultimately, this fundamental principle of biology has given us enormous material wealth and intellectual and emotional insight. For some reason, though, we now treat both time and diversity as mortal enemies: We kill off biological species at a rate faster than most natural disasters could, and we thrive on instant gratification to "kill" that pesky time that it takes to wait.

Most of us will be the poorer for it, but it's at least heartening that there is serious and insightful science that bucks this trend.

2 • Share ›

bill sardi • 8 hours ago

Shows presumed evidence of epigenetic adaptation or Mendelian variation, not evolution (new species).

0 • Share ›

John Adams • 2 days ago

Watching 8 drops of pitch fall through a funnel over 85 years??

Sheesh...and I thought MY job was boring...

0 • Share ›