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Evolution experiment with bacteria challenges conventional wisdom about size and the cost of production

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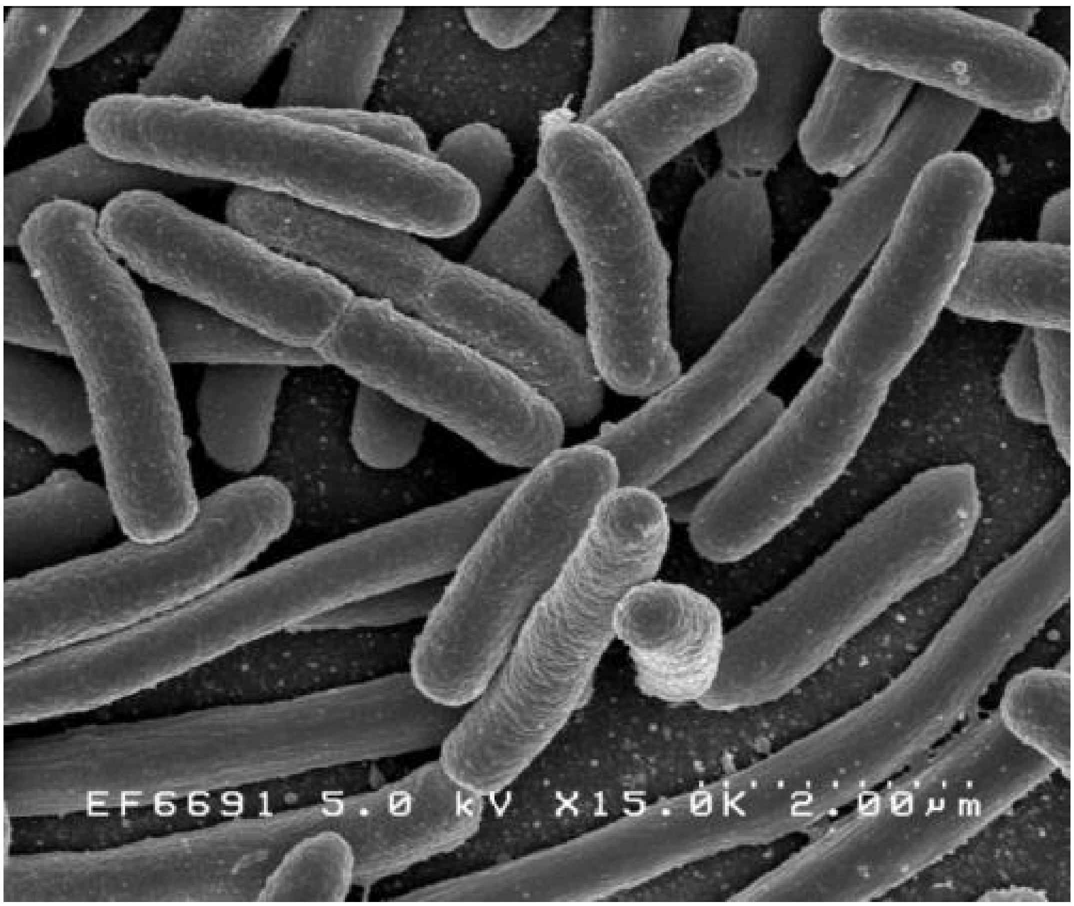

Escherichia coli. Credit: Rocky Mountain Laboratories, NIAID, NIH

In 1988, a biologist at Michigan State University, Richard Lenski, set up

12 flasks of E. coli and his group has maintained and followed their evolution ever since. Periodically, subsamples are frozen, enabling scientists to compare the bacteria at different points in time by bringing them back to life.

Over time the evolving E. coli have grown bigger; after 60,000 generations, cells are roughly twice the size of their ancestors. But has this increase in size been accompanied by changes we expect to see in metabolism and population size and growth rates?

Researchers at the Monash University Center for Geometric Biology have collaborated with Richard Lenski to find out. The results are published today in *Proceedings of the National Academy of Sciences (PNAS)*.

Metabolism dictates the rate at which organisms transform energy into maintenance and production.

While larger species have higher metabolic rates, they are actually more efficient and so have lower metabolic rates relative to their size. So, while smaller species have higher population densities and can reach those densities faster, total population mass is greater in larger species (think mice and elephants).

But does the above hold true within a species?

Often the size range within a species isn't particularly large, making inferences about size difficult to test.

The aptly named "Lenski Lines" circumvent this problem. Richard's lab sent frozen samples of the original E. coli—the ancestors, plus samples from 10,000 and 60,000 generations of evolution.

Project leads from the Monash University School of Biological Sciences, Professor Dustin Marshall and Dr. Mike McDonald, set about reviving the cells and measuring cell size, metabolism, population size and population growth.

"We found that as the cells grew bigger through evolutionary time, metabolic rates increased but were lower relative to their size, as predicted by theory," said Professor Marshall.

"Also anticipated by theory, populations of larger cells had lower population densities but higher biomass' than their smaller ancestors," he said.

"The big surprise and in stark contrast to theory, was that populations of larger cells, despite their relatively lower metabolism grew faster than smaller cells."

Dr. McDonald said it was often assumed that the energy required to produce a new individual was directly proportional to its mass, but this experiment has shown it is not necessarily the case.

"Why then, would a larger cell be cheaper to build and maintain?"

E. coli cells use up a lot of energy maintaining ion gradients across cell membranes. As larger cells have smaller surface areas relative to mass they should also have lower maintenance costs than smaller cells. The evolved cells also have slightly smaller genomes than the smaller ancestral cells, so the costs of genome replication are lower for larger cells.

Further, the evolved cells have fine-tuned their genetic components in this highly predictable environment, reducing the costly expression of unneeded transcripts and proteins.

"Remarkably, it seems evolution can decouple the costs of production from size; there is no downside to increasing growth rates for the larger evolved cells in terms of yield," Dr. McDonald said.

More information: Dustin J. Marshall et al, Long-term experimental evolution decouples size and production costs in Escherichia coli, *Proceedings of the National Academy of Sciences* (2022). DOI: 10.1073/pnas.2200713119

Provided by Monash University

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