Soil bacteria evolve with climate change

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While evolution is normally thought of as occurring over millions of years, researchers at the University of California, Irvine have discovered that bacteria can evolve in response to climate change in 18 months. In a study published in the *Proceedings of the National Academy of Sciences*, biologists from UCI found that evolution is one way that soil microbes might deal with global warming.

Soil microbiomes—the collection of bacteria and other microbes in soil—are a critical engine of the global carbon cycle; microbes decompose the dead plant material to recycle nutrients back into the ecosystem and release carbon back into the atmosphere. Multiple environmental factors influence the composition and functioning of soil microbiomes, but these responses are usually studied from an ecological perspective, asking which microbial species increase or decrease in abundance as environmental conditions change. In the current study, the UCI team investigated if bacterial species in the soil also evolve when their environment changes.

"We know that evolution can occur very fast in bacteria, as in response to antibiotics, but we do not know how important evolution might be for bacteria in the environment with ongoing climate change," said Dr. Alex Chase, the lead author of the study and a former graduate student at UCI.

Several inherent characteristics should enable soil microbes to adapt rapidly to new climate conditions. Microbes are abundant and can reproduce in only hours, so a rare genetic mutation that allows for adaptation to new climate conditions might occur by chance over a short time frame. However, most of what is known about bacterial evolution is from controlled laboratory experiments, where bacteria are grown in flasks with artificial food. It was unclear whether evolution happens fast enough in soils to be relevant to the effects of current rates of climate change.

"Current predictions about how climate change will affect microbiomes make the assumption that microbial species are static. We therefore wanted to test whether bacteria can evolve rapidly in natural settings such as soil," explained Dr. Chase.

To measure evolution in a natural environment, the researchers deployed a first-ever bacterial evolution experiment in the field, using a soil bacterium called Curtobacterium. The researchers used 125 "microbial cages" filled with microbial food made up of dead plant material. (The cages allow the transport of water, but not other microbes.) The cages then exposed the bacteria to a range of climate conditions across an elevation gradient in Southern California. The team conducted two parallel experiments over 18 months measuring both the ecological and evolutionary responses in the bacteria.

"The microbial cages allowed us to control the types of bacteria that were present, while exposing them to different environmental conditions in different sites. We could then test, for instance, how the warm and arid conditions of the desert site affected the genetic diversity of a single Curtobacterium species," said Dr. Chase.

After 18 months, the scientists sequenced bacterial DNA from the microbial cages of the experiments. In the first experiment containing a diverse soil microbiome, different Curtobacterium species changed in abundance, an expected ecological response. In the second experiment over the same time frame, the genetic diversity of a single Curtobacterium bacterium changed, revealing an evolutionary response to the same environmental conditions. The authors conclude that both ecological and evolutionary processes have the potential to contribute to how a soil microbiome responds to changing climate conditions.

"The study shows that we can observe rapid evolution in soil microbes, and this is an exciting achievement. Our next goal is to understand the importance of evolutionary adaptation for soil ecosystems under future climate change," said co-author Jennifer Martiny, professor of ecology and evolutionary biology who co-directs the UCI Microbiome Initiative.

More information: Alexander B. Chase et al, Adaptive differentiation and rapid evolution of a soil bacterium along a climate gradient, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2101254118

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