New formula provides key to predicting microbial growth

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Salvatore Calabrese, Ph.D., assistant professor in the Department of Biological and Agricultural Engineering meets with students. Credit: Laura McKenzie

Just like cars need fuel to run, microorganisms need energy to live.

We know combustion engines, such as in cars or power plants, lose efficiency when they run faster—similarly, a new publication by a Texas A&M AgriLife Research scientist and his team reveals that microbes lose efficiency as their metabolic rates increase.

Microorganisms' ability to use energy efficiently in various environmental conditions has consequences for the global climate and carbon cycle, and for biotechnological applications that could address global warming.

"Energetic scaling in microbial growth," published in *Proceedings of the National Academy of Sciences*, provides a new mathematical model for scientists to examine these metabolic processes in microorganisms.

Lead researcher Salvatore Calabrese, Ph.D., assistant professor in the Department of Biological and Agricultural Engineering in the College of Agriculture and Life Sciences at Texas A&M University, Bryan-College Station, said the discovery is a fundamental step toward a deeper understanding of the energetic principles governing all living systems.

Predicting microbial growth amid climate change

Relying on extensive laboratory data, Calabrese and colleagues from University of Stockholm, Sweden, and University of Waterloo, Canada, focused on bridging biochemistry and thermodynamics to calculate metabolic activity, such as the energy required for growth, and ultimately the thermodynamic efficiencies of microorganisms. Using statistical techniques, they found how energy efficiencies can be predicted from well-established microbial parameters commonly measured in the laboratory, such as the rate at which microbes grow.

"We knew we could look at microbes as tiny thermodynamic machines," he said. "Through detailed analysis of their energetics, we found how their efficiency is predictable. And that predictability and this mathematical formulation will allow other scientists to understand how microbes respond to changing environmental conditions."

The discovery, which unlocks our understanding of how these important organisms grow under changing environmental conditions, is central to predicting not only the impact of changes in climate and land use on soils and ecosystems, but also how soils, through carbon sequestration, may help mitigate global warming.

"Soil microorganisms are fundamental to transform organic matter into forms that can be stabilized and stored in soils," said co-author of the study Stefano Manzoni, Ph.D., associate professor at Stockholm University, Stockholm, Sweden. "More efficient microorganisms can help store more carbon in the soil—that is why our results are important for climate change research,"

From engineering to microbiology

Calabrese was excited to find he could apply his engineering knowledge to link these reactions in microorganisms to quantifiable and predictable results.

Microbial thermodynamics is similar to the workings of a car engine, he said. A car engine burns fuel to create energy, whereas microorganisms in the soil feed on organic carbon to produce energy.

Just as it's predictable that a car driving 70 mph will lose efficiency due to factors like wind resistance and burn more fuel in the same distance than if traveling 55 mph, Calabrese's team found a way to predict how microbes lose efficiency as their metabolic rates increase.

After almost two years of intensive research, Calabrese and collaborators produced a simple way to consistently estimate microbial energetics. Now, Calabrese and research colleagues are working toward answering questions regarding microorganisms' conditional responses to factors like nitrogen and organic matter.

Calabrese expects the publication to help scientists around the globe.

"The hope is that this will propel scientific discovery within general thermodynamic theories extending into all forms of biological and eventually ecological systems and how they are all connected," he said. "Microbes are a fundamental basis for all life, and this discovery provides a launching point for that exploration."

More information: Salvatore Calabrese et al, Energetic scaling in microbial growth, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2107668118

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