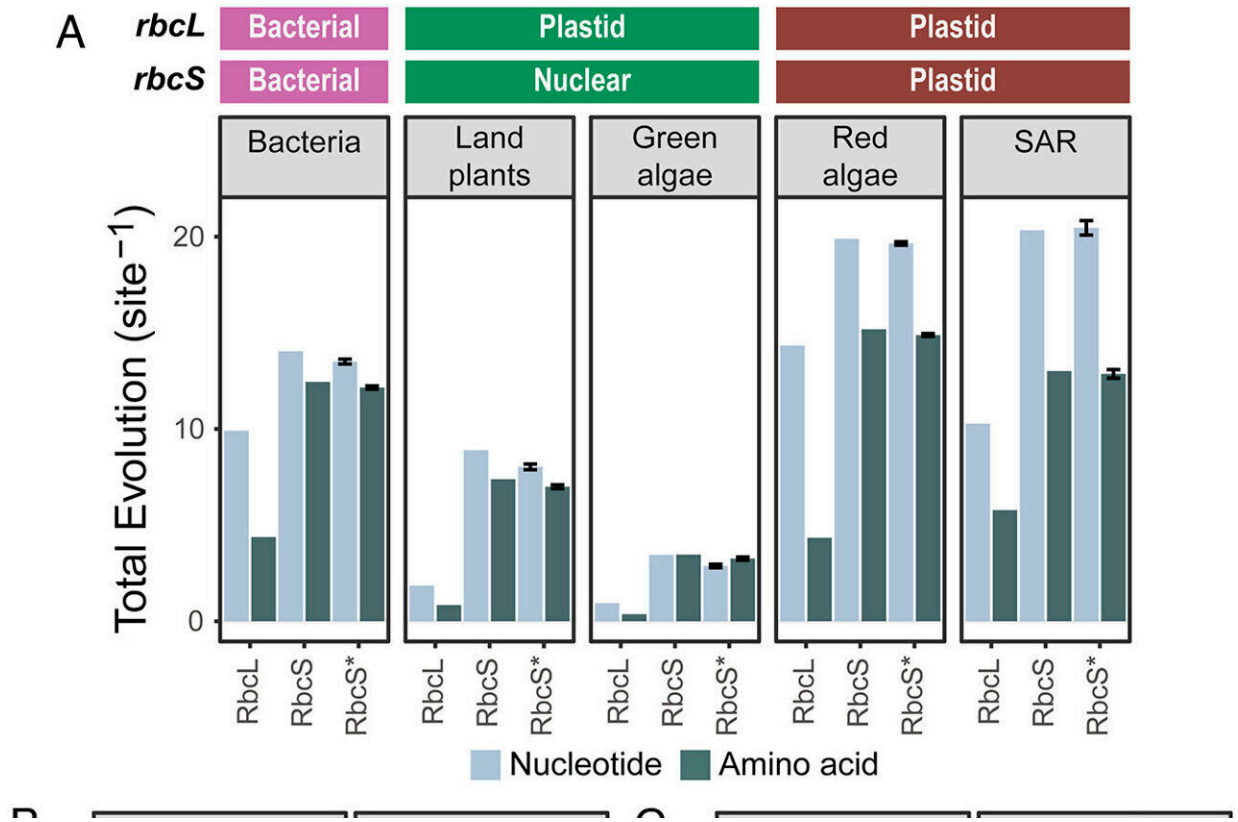
Study finds world's most prolific CO_2-fixing enzyme is slowly getting better

March 7 2024



The extent of molecular evolution in rubisco during the radiation of each taxonomic group. Credit: *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2321050121

New research led by the University of Oxford has found that rubisco—the enzyme that fuels all life on Earth—is not stuck in an

evolutionary rut after all. The largest analysis of rubisco ever has found that it is improving all the time—just very, very slowly. These insights could potentially open up new routes to strengthen food security.

The paper "Rubisco is evolving for improved catalytic efficiency and CO_2 assimilation in plants," has been published in *Proceedings of the National Academy of Sciences.*

The most abundant enzyme on Earth, rubisco, has been providing the energy that fuels life on our planet for the last three billion years. While rubisco fixes billions of tons of CO_2 each year, the enzyme is notoriously inefficient. This has created a biological paradox that has puzzled researchers for decades. Why is the enzyme that has been fueling life for over 3 billion years not much better at doing its job? Many plant scientists have debated whether the enzyme is stuck in an "evolutionary rut," making it impossible for it to get any better.

But new research from the University of Oxford has revealed that rubisco is continually improving, but that this improvement is occurring at a glacial pace.

Lead author Jacques Bouvier (a DPhil student in the Department of Biology, University of Oxford) said, "Our research demonstrates for the first time that evolution is consistently improving rubisco and that further improvement of the enzyme is possible. Importantly, this insight provides renewed optimism for efforts to engineer the enzyme to help feed the world."

The researchers analyzed rubisco gene sequences from across a wide range of photosynthetic organisms and quantified the rate of rubisco evolution for the first time. They found that its sequence has altered in minute increments of just one DNA base change every 900,000 years—a stark contrast from the COVID-19 genome, for example, which is

evolving one base change every two weeks. This puts rubisco in the 1% of slowest evolving genes on Earth.

Despite this slow rate of change, the researchers found that the enzyme is harnessing this evolution to get better at fixing CO_2. The authors also found that this slowly improving CO_2 fixation is resulting in improvements to photosynthesis; plants are evolving to get better at turning CO_2 into sugar, but the rate of improvement is so slow that it appears frozen.

For decades scientists have aspired to engineer an improved rubisco to boost growth and yields of crop plants. But despite much effort, success has been limited, and many have wondered whether rubisco is already optimized, making these attempts futile. However, the insights from this study offer renewed hope. In particular, unraveling the mystery of what is holding back rubisco's rate of evolution may uncover new ways of enhancing crop yields.

Jacques Bouvier added, "Because rubisco assimilates the sugars which fuel life on Earth, improving this enzyme is one of the most promising avenues to help combat food insecurity. There has been heated debate as to whether there is scope to improve the enzyme; our new research provides a clear answer to this question. If evolution can improve rubisco, so can we!"

Senior author Professor Steven Kelly (Department of Biology, University of Oxford) said, "We have shown that rubisco is not frozen in time but is instead continually evolving to get better. We now need to understand the factors that are holding rubisco back to enable us to realize its true potential."

This new insight offers encouragement to efforts that aim to increase yields in food, fiber, and fuel crops by targeting rubisco engineering.

Improving rubisco could be key to supporting the food needs of a growing global population.

More information: Jacques W. Bouvier et al, Rubisco is evolving for improved catalytic efficiency and CO_2 assimilation in plants, *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2321050121

Provided by University of Oxford