Repairing the photosynthetic enzyme Rubisco

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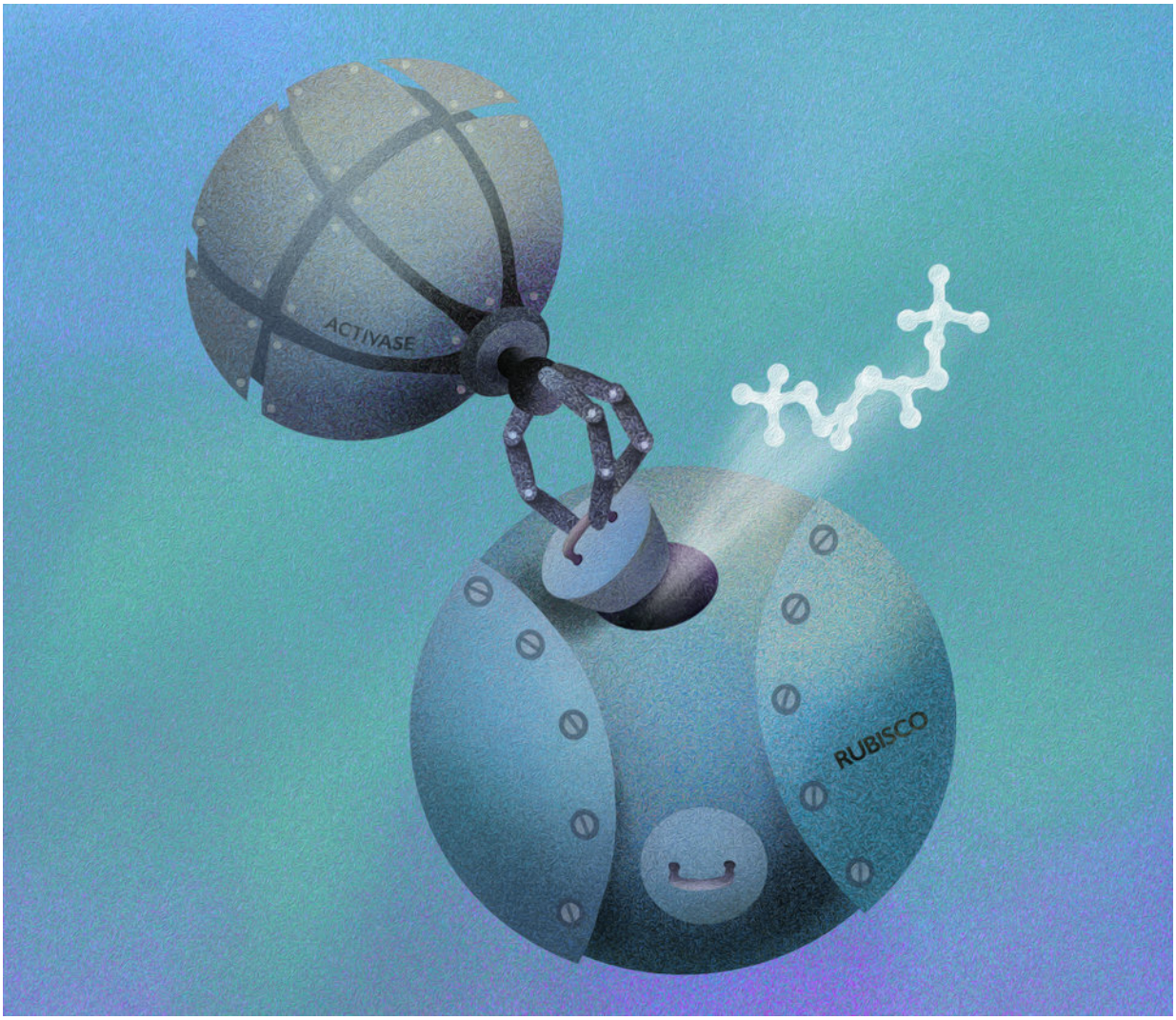

Rubisco activase catalyzes the opening of the active site pocket of Rubisco and facilitates release of the inhibitory sugar. The image is an artistic interpretation of the mechanism. Artwork: Julia Kuhl;. Credit: Manajit Hayer-Hartl MPI of Biochemistry

Manajit Hayer-Hartl, head of the research group "Chaperonin-assisted Protein Folding," has a long-standing interest in the central enzyme of photosynthesis called Rubisco. Her team has already reported on many of the interacting partners of Rubisco that are required for the folding and assembly of this highly abundant protein. In the current study, they have elucidated how Rubisco activase works. As the name indicates, this enzyme is critical for repairing Rubisco once it has lost its activity. The study was published in *Cell*.

The enzyme Rubisco catalyzes the assimilation of CO_2 from the atmosphere into organic matter. This is the central step in photosynthesis that generates sugar molecules for the production of essentially all biomass. Despite its pivotal role, Rubisco works relatively slowly and is easily inhibited by sugar products. By improving the function of Rubisco Hayer-Hartl hopes to be able to boost the process of photosynthesis. The goal is to address the growing global demand for food and reduce the current greenhouse gas-induced climate change.

The enzyme Rubisco activase, Rca, is present in plants, algae and certain cyanobacteria. Rca is a ring-shaped complex of six subunits with a central pore. How exactly Rca interacts with the inhibited Rubisco and releases the bound sugar from the active site pocket of Rubisco, restoring its CO_2 fixing activity, was unclear until now. With the help of biochemistry, crystallography and cryo-electron microscopy, Hayer-Hartl & colleagues have now succeeded in deciphering the molecular mechanism of a cyanobacterial Rca.

They discovered that the Rca grabs the N-terminal tail of Rubisco and by pulling and pushing actions, using the energy of ATP, opens the active site pocket. This results in the release of the inhibitory sugar molecule. In cyanobacteria Rubisco is packaged into specialized micro-compartments called carboxysomes, in which a high concentration of CO_2 is generated to facilitate the function of Rubisco.

In an earlier study, Hayer-Hartl showed how Rubisco is recruited into carboxysomes via interactions with the SSUL domains of the scaffolding protein CcmM. Interestingly, the researchers now found that Rca is recruited into carboxysomes using a very similar trick. The Rca hexamer also contains SSUL domains that dock onto Rubisco during carboxysome formation. This makes sure that enough Rca is present inside carboxysomes to perform its essential repair function. Thus, Rca not only functions in Rubisco activation but also mediates its own recruitment into carboxysomes.

Manajit Hayer-Hartl concludes: "Rca is absolutely required for Rubisco to function optimally. Deciphering its mechanism and dual function in cyanobacteria will further help us to make photosynthesis more effective in the future. Hopefully, this will get us closer to our ultimate goal, to increase agricultural productivity."

More information: Mirkko Flecken et al, Dual Functions of a Rubisco Activase in Metabolic Repair and Recruitment to Carboxysomes, *Cell* (2020). DOI: 10.1016/j.cell.2020.09.010

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