Researchers discover feedback mechanism in photosynthesis that protects plants from damage by light

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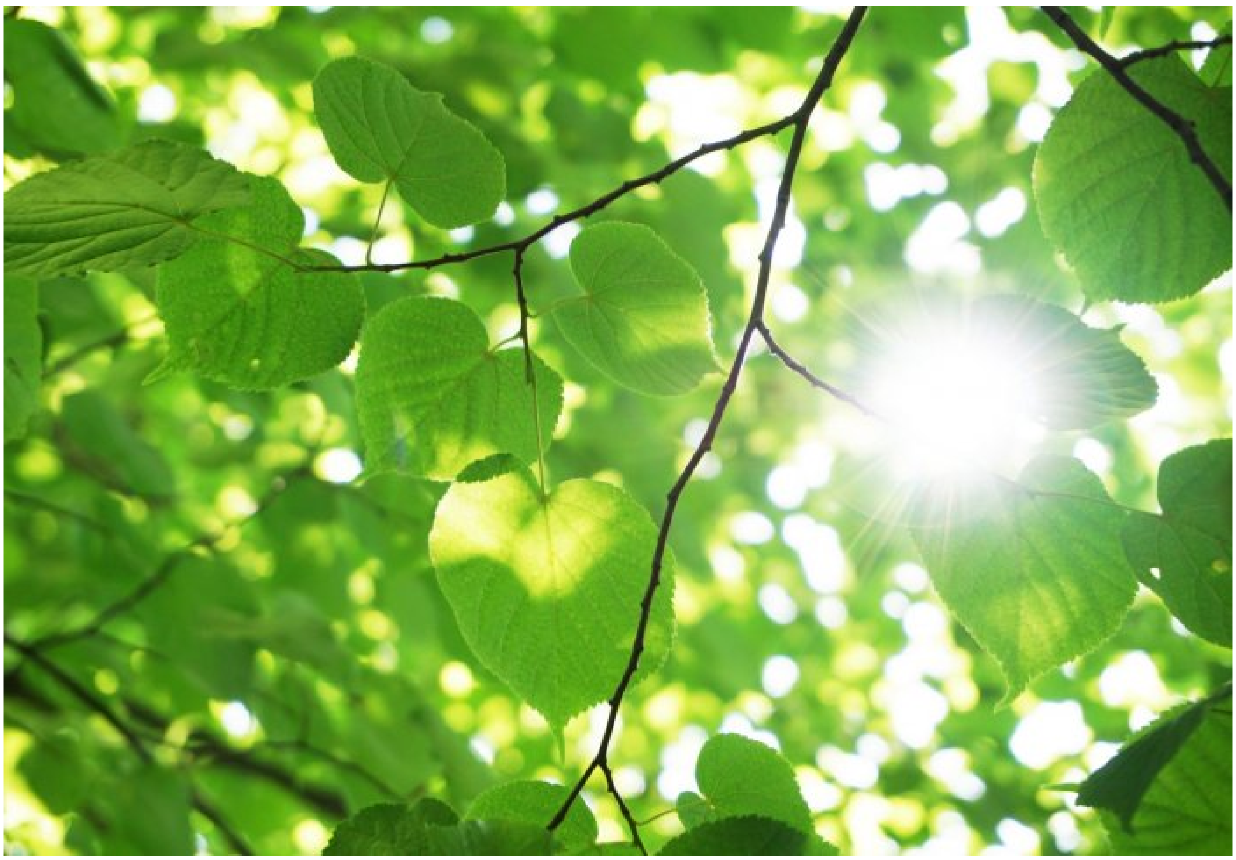

Credit: Imperial College London

Scientists at Imperial College London have discovered a feedback mechanism at the heart of photosynthesis that protects plants from damage by light.

The researchers have discovered that the key enzyme in photosynthesis can tune its activity to avoid being damaged by light and oxygen.

Knowing how photosynthesis is regulated and protected could allow scientists to improve the process, potentially making agriculture and food production more efficient.

For example, understanding how this regulatory mechanism works could help researchers to identify the factors that are beneficial for plant growth and to define how to adjust these in order to optimise growth in controlled cultivation.

Photosystem II, the central enzyme in photosynthesis, uses solar energy to remove electrons from water. The electrons are used to fix carbon dioxide from the atmosphere, creating a form of carbon that constitutes the fuel and building blocks for life. Photosystem II changed the planet by putting most of the energy into the biosphere and all of the oxygen into the atmosphere.

Backed-up electrons

When leaves close their pores to prevent water loss, this also prevents air exchange so that carbon dioxide cannot enter the system. As the carbon dioxide inside the leaf is used up, the electrons have nothing left to react with and so they build up.

Although carbon dioxide is not entering the system, light still is, generating excess electrons. As the electrons have nowhere to go, they instead engage in 'back-reactions' that form a 'killer molecule' called singlet oxygen. This killer molecule can damage the photosystem II enzyme.

Now, by using a technique called spectro-electrochemistry, researchers have discovered a mechanism that protects the enzyme from this damage. The trapped electrons trigger the release of a bicarbonate molecule from the enzyme, which was previously thought to be constantly bound to it.

The new study, published today in *Proceedings of the National Academy of Sciences*, shows that this bicarbonate release not only slows down the water-splitting reaction but crucially also protects the enzyme from light damage due to the harmful back-reactions.

Textbook stuff

Bicarbonate is formed when carbon dioxide dissolves in water, so its concentration is related to the amount of carbon dioxide in the local environment.

As well as low carbon dioxide levels causing electrons to build up and trigger the release of bicarbonate, the study also suggests the possibility that the level of carbon dioxide itself in the local leaf environment could impact on the bicarbonate binding.

"This is such an intuitive feedback mechanism at the heart of biology that I think it will go into school textbooks," said lead author, Professor Bill Rutherford FRS from the Department of Life Sciences at Imperial.

"Now that we understand this new mechanism in the lab, the next step is to define when it kicks in out there in the field - not to mention the forest, greenhouse, plant pot, sea, lake and pond."

Dr Andrea Fantuzzi, co-lead author also from the Department of Life

Sciences at Imperial, added: "The role of bicarbonate has long been a mystery. Otto Warburg, Nobel laureate, friend of Einstein and one of the twentieth century's leading biochemists, puzzled over this problem in the 1950s.

"Now the mystery is solved and a new regulatory mechanism defined. Not only is the question solved, but it could have real implications for understanding limitations to plant growth."

The dangers of overcharging your plants

The newly-discovered protection mechanism involves 'redox tuning', a process that Professor Rutherford has championed as being the key to the survival of life in the presence of oxygen. Using the same thinking he has also worked with a group from Michigan State University to explain how light damages Photosystem II, another long-running contentious issue.

The group discovered that variations in the intensity of light generate pulses of electrical field. These spikes in the field enhance the harmful back-reaction route for electrons, damaging Photosystem II.

The results of this second study, published this month in the journal eLife, showed that even the flickering of light caused by leaves shifting in the wind could create dangerous pulses of the internal electric field resulting in photo-inhibition, a process that can limit plant growth. This new knowledge could have important repercussions on the quest to improve photosynthesis for more sustainable agriculture.

More information: Bicarbonate-induced redox tuning in Photosystem II for regulation and protection. *PNAS* 2016 ; published ahead of print October 10, 2016, DOI: 10.1073/pnas.1608862113