Uncovering quantum secret in photosynthesis

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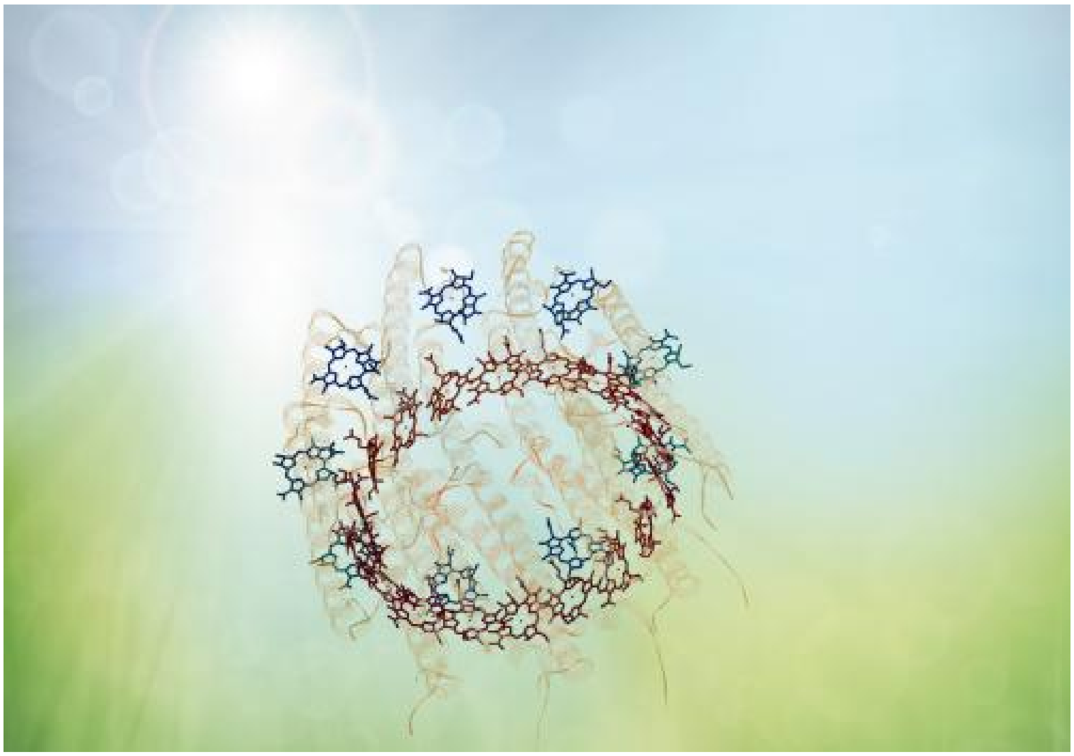

In photosynthesis sunlight is captured and transported by highly specialised antenna proteins. Surprisingly these proteins act as quantum machines and use a quantum transport mechanism to efficiently guide the light and finally store the energy in their reaction centres. Researchers from ICFO -- the Institute of Photonic Science in Barcelona have for the first time tracked this energy flow in individual proteins and discovered that the quantum coherences makes the light flow in the antenna protein immune to the ubiquitous external natural turmoil. Credit: ICFO

The efficient conversion of sunlight into useful energy is one of the challenges which stand in the way of meeting the world's increasing energy demand in a clean, sustainable way without relying on fossil fuels. Photosynthetic organisms, such as plants and some bacteria, have mastered this process: In less than a couple of trillionths of a second, 95 percent of the sunlight they absorb is whisked away to drive the metabolic reactions that provide them with energy. The efficiency of photovoltaic cells currently on the market is around 20 percent. What hidden mechanism does nature use to transfer energy so efficiently? Various research groups around the world have shown that this highly efficient energy transport is connected to a quantum-mechanical phenomenon. However, until now, no one had directly observed the possible impacts of such a quantum transport mechanism at work at room temperature.

In an article published in the journal *Science*, researchers from ICFO-Institute of Photonic Sciences, in collaboration with biochemists from the University of Glasgow, have been able to show for the first time at ambient conditions that the quantum mechanisms of energy transfer make phyotosynthesis more robust in the face of environmental influences. The quantum phenomenon responsible, known as coherence, is manifested in so-called photosynthetic antenna proteins that are responsible for absorption of sunlight and energy transport to the photochemical reaction centers of photosynthesis.

In order to observe quantum effects in photosynthesis, the research group led by Niek van Hulst developed a pioneering experimental technique. Energy transport during photosynthesis is extremely fast and takes place at a molecular scale. To observe these processes they pushed the ultrafast spectroscopy techniques to the single-molecule limit. This involves sending ultrafast femtosecond light flashes to capture a high-speed series of 'pictures' of the states of individual antenna proteins after light absorption (during one femtosecond light travels only one hundredth of the diameter of a human hair, while in one second it travels from earth to moon). With these "snapshots" the researchers are able to understand how solar energy is transported through single proteins. "We have been able to observe how energy flows through sunlight absorbing photosynthetic systems with unprecedented spatial and temporal resolution. This allowed us to observe the fundamental role of quantum effects in photosynthesis at ambient conditions" explains Richard Hildner, first author of the publication.

Van Hulst and his group have evaluated the energy transport pathways of separate individual but chemically identical, antenna proteins, and have shown that each protein uses a distinct pathway. The most surprising discovery was that the transport paths within single proteins can vary over time due to changes in the environmental conditions, apparently adapting for optimal efficiency. "These results show that coherence, a genuine quantum effect of superposition of states, is responsible for maintaining high levels of transport efficiency in biological systems, even while they adapt their energy transport pathways due to environmental influences" says van Hulst.

The results presented raise fascinating questions. Was the exploitation of quantum effects in photosynthesis driven by evolution to achieve the extraordinary efficiencies, or in other words did quantum transport outcompete other mechanisms during evolution? Are there other biological processes in which quantum effects play an important role? In the case of light-harvesting proteins quantum transportation allows extreme transport energy efficiency and robustness. This discovery could lead to new research lines aiming at the developments of a new generation of solar cells that mimic these quantum coherences for efficient energy transfer.

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