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Nature inspires technology

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Secrets in the Sun. We need to understand how leaves are able to maximize the amount of energy that they absorb from sunlight.

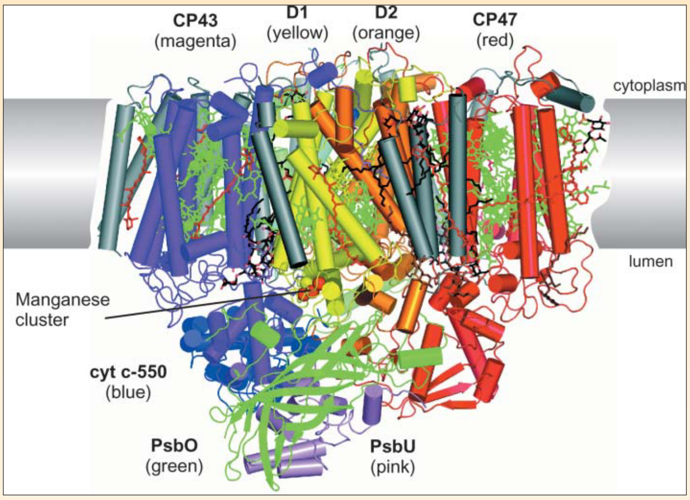
POWERED BY THE SUN: PLANTS CAN SHOW US HOW

Our attempts to tap in to the Sun's energy to power our daily lives have fallen far short of the efficiency levels that we need to achieve to take the pressure off fossil fuels. Understanding how plants exploit sunlight may hold the key to our use of solar power.

Using sunlight to power our homes and offices worldwide is an unaccomplished dream owing to the still-inefficient technology that we currently use to capture and utilize solar energy. The study of photosynthesis in plants and cyanobacteria could provide new clues by explaining how they absorb almost 100% of the sunlight that reaches them, and how they transform it into other forms of energy.

Three teams from Berlin have used the X-ray source at the ESRF to investigate the molecular structure of the machinery of photosystem II and the kinetics of the photosynthetic process that converts water into atmospheric oxygen as well as electrons and protons that finally reduce carbon dioxide to carbohydrates.

In plants, algae and cyanobacteria, photosynthesis is initiated at photosystem II (PSII), a large complex comprising proteins and pigments that are embedded in a membrane. By capturing sunlight, PSII produces the energy required to power the oxidation of water to atmospheric oxygen. It contains four manganese atoms and one calcium atom, which are known to be at the centre of the catalytic reaction. Five intermediate states have been proposed in the process of photosynthesis – described by the "Kok cycle" – but, till recently, the existence of only four had been proved.



PSII occurs as homodimer. The structure of one monomer looking along the plane of the membrane. The main protein subunits are shown: α-helices as cylinders, chlorophylls (green), carotenoids (red) and lipids (black) as wire models.

Having isolated PSII from spinach, Holger Dau's group from Freie University has identified the missing state with the help of the ESRF. This is particularly important because it is directly involved in the formation of molecular oxygen. Furthermore, the team suggests an extension of the cycle with an additional intermediate and proposes a new reaction mechanism on a molecular basis for the release of dioxygen. This gives new insight into the mechanism of photosynthesis.

To complement this view, and using the completely different technique of macromolecular crystallography, two other teams – one preparing and crystallizing PSII and one carrying out crystal structure analysis – have presented the most detailed model of PSII yet.

A complex of 20 protein subunits and 77 pigments was revealed in near-atomic detail, which completed and partly corrected earlier models. The researchers concluded that a high degree of flexibility is required for the protein function and that this flexibility is "lubricated" by a number of organized lipid molecules.

"This new view of the spatial arrangement of the different components of PSII furthered our understanding concerning the electron- and energy-transfer mechanisms," explained Athina Zouni of the Technical University and Wolfram Saenger of Freie University, the heads of the two teams.

Intermediate state is identified

In both studies the use of synchrotron light was crucial: "A very intense and stable X-ray beam is necessary to study the kinetics of such a complex, highly diluted protein present in the investigated spinach sample," explained Pieter Glatzel, head of beamline ID26, where the experiments on fluorescence were carried out. They flashed the sample with a laser and registered the change using X-ray fluorescence every 10 µs to find out how different oxidation states developed. When carefully analysing the reaction kinetics, they observed a time delay before the O_2-evolving step that unambiguously proved the existence of the long-searched-for intermediate state.

In the case of the structural team, much effort was spent to improve the purity of PSII isolated from cyanobacteria with the aim of extending the resolution of the X-ray diffraction as far as possible. Even at the achieved resolution of 3.0 Å the manganese and calcium atoms are not clearly resolved. A resolution of 2.8 Å or even higher will ultimately be required to satisfy the chemists' view of PSII.

How far are we from using the Sun's energy to sustain us? Michael Haumann and Bernhard Loll, the main authors of the publications generated by this work, claimed: "These are important results that will have an impact in the photosynthesis community. They help our understanding of how solar energy is used in plants and contribute to the efforts to produce more efficient solar cells for our needs." ●

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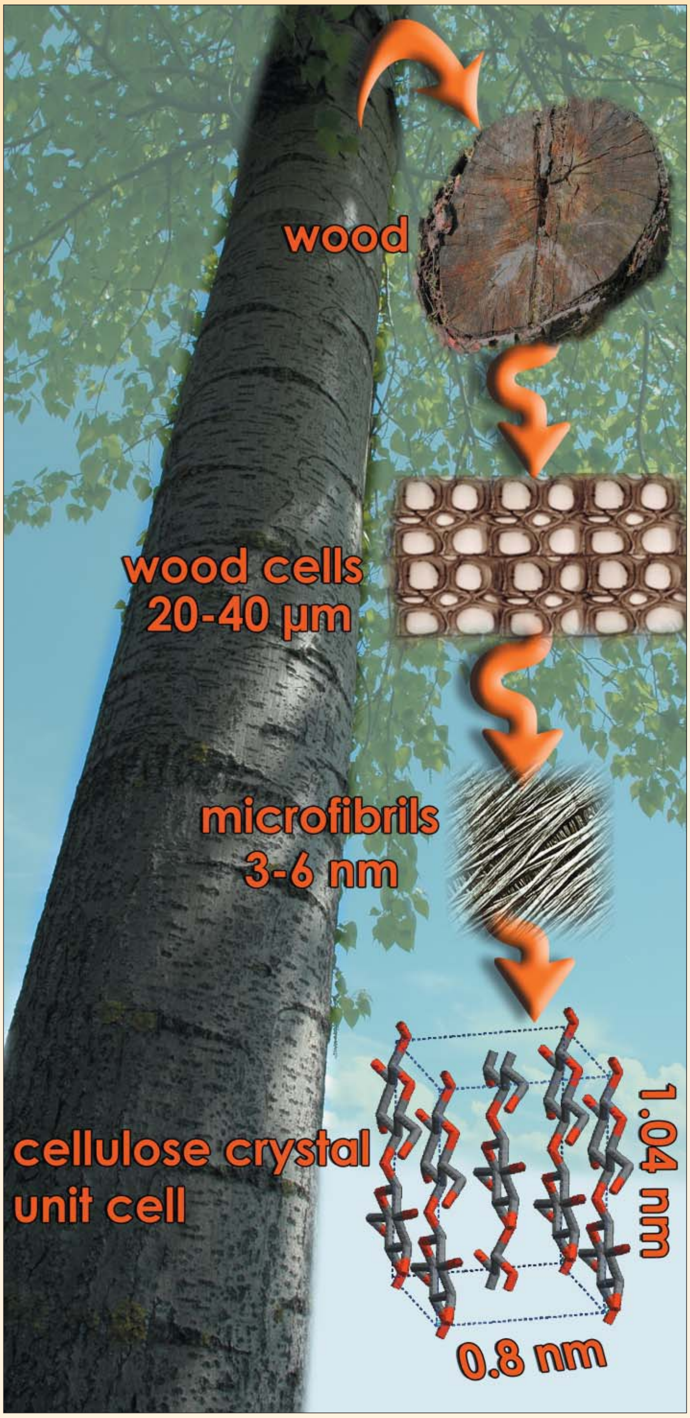
WHAT GIVES WOOD ITS EXCELLENT MECHANICAL PERFORMANCE?

Despite thousands of years of use and many years of research, scientists still don't fully understand the mechanism of wood, and some of them come to the ESRF to study its structure at the micrometre scale.



Strong but flexible. Thanks to wood's hierarchical structure.