Editorial

Sensors and Transducers in the Landscape of Photosynthesis

Photosynthesis is a paramount biological process enabling and sustaining aerobic life on Earth. Embedded into asymmetrically charged lipid bilayers, individual macromolecular assemblies perform the vital light-harvesting, charge-separation and water splitting functions to store solar energy in a biochemical form. In order to increase light capture and photoprotection in evolutionary divergent organisms, light-harvesting complexes (LHC) diversified in several LHC protein superfamilies distinguishable by their sovra-molecular arrangement, primary structure and bound active pigments, including the LHC containing Chl*a* and *b*, the fucoxanthin-Chl *a/c*, the phycobilin-Chl *a*, or the peridinin-Chl *a* proteins (PCPs). The oxygenic photosynthetic machinery comprises Photosystem I and II (PSI and PSII), the cytochrome *b6f* complex (Cyt *b6f*) and the ATP synthase. These multisubunit protein complexes function as bioenergy converters, capturing the energy of sunlight and transducing it into chemical energy. Being able to perform light-induced charge-separation necessary for the light energy conversion, PSI and PSII behave as the most efficient molecular photovoltaics producing and driving electrical currents. Integrated in a battery-like circuit, the Cyt *b6f* electrically connects the activity of PSII and PSI, empowering electron transfers and producing the proton gradient leading to the synthesis of ATP. At the end of the circuit, ferredoxin and ferredoxin:$NADP^+$ oxidoreductase isoproteins work as one-to-two electron switches to produce chemical reducing equivalents in the form of NADPH.

Acting at micro- and nano-scale levels as well as on a femto-picosecond timescale, macromolecular photosynthetic complexes are receiving renewed attention due to the possibility of being used in the construction of optoelectronic devices and mono- and/or multi-molecular layers of either natural or engineered subcomponents for the development of biosensors, biochips and photovoltaic semiconductors.

This Hot-Topic issue charts an updated overview on the structural-functional features of the most promising photosynthetic proteins suitable for biotechnological applications. Caffarri and colleagues discuss and compare various aspects of the organisation, functioning and regulation of plant photosystems by comparing them for similarities and differences as obtained by structural, biochemical and spectroscopic investigations. Ihssen and co-workers cover peculiar aspects of LHC proteins sovra-molecular arrangements obtained by bacteria, cyanobacteria and algae and explore their efficiency in light of their possible exploitation as solar fuel producers in photoelectrochemical cells.

The fine-tuning of photosynthetic electron transfer and PSII photoinhibition is reviewed in the manuscript by Roach and Krieger-Liszkay. The authors describe the impact of different multi-scale regulated mechanisms on photosynthetic efficiency, providing a perspective discussion for the development of more stable PSII-based biosensors.

Plant and bacterial photoactive reaction centers receive particular attention as bio-sensing elements for monitoring emerging pollutants, since electron transfer can be affected by xenobiotic compounds and easily detected. Focusing on green microalgae, Lambreva and co-workers provide a binding energy overview of the primary and secondary electrons acceptors to their binding niche in PSII in addition to highlight possible hot-spots for protein engineering improving thermodynamic stability. Dealing with bacterial organisms, the manuscript by Nagy and colleagues demonstrated the high stability, reliability and functioning of purified RC proteins immobilized into bio-nanocomposite structures for either biosensing or energy conversion.

Carbonera and co-workers explore the amazing photophysical properties of PCPs providing in-depth insights into energy transfer mechanisms, addressing their improved functioning in hybrid nanostructures and usefulness for the development of artificial light harvesting antennae.

The manuscript by Goss and Hanke describe the functional consequence of different expression pattern of ferredoxin:$NADP^+$ oxidoreductase isoproteins, working as one-to-two electron switches in generating reducing equivalents, and discuss possible fates of electrons along linear and cyclic photosynthetic electron transfer. Campi and colleagues round out this hot-topic issue highlighting and proving the pivotal role of spatial distribution of atomic and molecular self-assembly in determining an efficient electron transfer in both biological and material science. In addition, the authors propose novel *lab-on-chip* techniques to control spatial distribution of molecules at nano-scale.

In this era of nanotechnology, systems biology and synthetic biology in which sensors and transducers dominate the scene, photosynthetic proteins are main actors indicating the way to their exploitation for the synthesis of artificial biomimetics. These peculiarities make photosynthesis research timely and intriguing even after 2.4 billion years of evolution.

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