Ultrafast processes in heme proteins: using light to monitor ligand dynamics and exchange, and CO-sensing

Ursula Liebl[1], Carolina Villamil Franco[1], Fevzi Daldal[2], Roberto Motterlini[3], Jean-Christophe Lambry[1], Marten H. Vos[1]

[1]LOB, Ecole Polytechnique, CNRS, INSERM, Université Paris-Saclay, 91128 Palaiseau, France

[2]Department of Biology, University of Pennsylvania, Philadelphia, PA 19104, USA

[3]INSERM, U955, Université Paris-Est, Créteil 94000, France

E-mail: marten.vos@polytechnique.edu

Heme proteins are active in a large variety of biological functions, including for instance sensing of signaling and environmental gases, and respiratory energy conversion. As the chemical bond between heme and external ligands like CO, NO or O_2 can be photodissociated, ultrafast photochemical methods are used to study reaction mechanisms and intermediates. One remarkable example is our recent spectroscopic demonstration of exchange between two different external heme ligands (NO and H_2O) occuring within a few picoseconds in the interior of a heme-based sensor protein.[1] In this presentation, we focus on two different emerging issues.

First, upon the identification in recent years of CO as a physiological messenger molecule, we recently started studying the heme domain of the bacterial RCOM2 CO-sensor protein. This macromolecule displays an extraordinarily high affinity for CO, to a point that CO can only be released by prolonged intense illumination. We have demonstrated that this is not due to the intrinsic photochemistry of the heme-CO bond, but to the thermodynamic properties of the heme pocket, which induces unprecedented quasi-100% heme-CO recombination on the picosecond timescale.[2] Present work focuses on a) the potential use of RCOM2 as a CO-scavenging and (optical) monitoring tool in biomedical and biotechnological applications and b) understanding how a protein with such a high CO affinity can actually physiologically function as a sensor. Preliminary experiments indeed indicate markedly different kinetic properties in the recently obtained full-length protein compared to the heme domain.

Second, following recent suggestions of high quantum yield heme photooxidation in the mitochondrial multi-heme membraneous complex cytochrome bc_1, we have performed an extensive study of this complex. We demonstrate that photodissociation from the heme iron and picosecond recombination of internal residues occurs, but no substantial photo-redox-chemistry.[3] A highly intriguing result concerns unexpected photo-induced signals that are not attributable to hemes, but rather to the, very weakly absorbing, [2Fe-2S] redox cluster in the complex. Photochemical effects of Fe-S centers have not been observed previously, and with the perspective of photo-initiating redox reactions involving such centers, presently this line of research is further explored.

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