conceivable that FDPs made the oxygenic photosynthesis possible in cyanobacteria. The Flv2 and Flv4 proteins are present only in β-cyanobacteria and their heterodimer forms an electron valve from Photosystem (PS) II, which functions in PSII photoprotection. The Flv1 and Flv3 proteins can be found in α and β-cyanobacteria, but also in green algae, mosses and ferns. They function on the reducing side of PSI and can transfer electrons directly to molecular O2 without formation of reactive oxygen species (ROS). The importance of Flv1 and Flv3 for the survival of cyanobacteria was unambiguously proven only recently by application of fluctuating light to mimic the constantly changing natural illumination conditions in aquatic environments. Furthermore, the existence of two “extra” genes that represent copies of flv1 and flv3 was identified in filamentous N2-fixing and heterocyst-forming cyanobacteria. These are heterocyst-specific FDPs and function in light-induced O2 uptake on the reducing side of PSI, thus protecting the nitrogenase enzyme against photooxidative damage.

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P5.2

The quantum design of photosynthesis
Rienk van Grondelle
VU University, Amsterdam, The Netherlands
E-mail: r.van.grondelle@vu.nl

Photosynthesis has found an ultrafast and highly efficient way of converting the energy of the sun into electrochemical energy. The solar energy is collected by light-harvesting complexes (LHC) and then transferred to the reaction center (RC) where the excitation energy is converted into a charged separated state with almost 100% efficiency. That separation of charges creates an electrochemical gradient across the photosynthetic membrane which ultimately powers the photosynthetic organism. The understanding of the molecular mechanisms of light harvesting and charge separation will provide a template for the design of efficient artificial solar energy conversion systems.

Upon excitation of the photosynthetic system the energy is delocalized over several cofactors creating collective excited states (excitons) that provide efficient and ultrafast paths energy transfer using the principles of quantum mechanics. In the reaction center the excitons become mixed with charge transfer (CT) character (exciton-CT states), which provide ultrafast channels for charge transfer. However, both the LHC and the RC have to cope with a counter effect: disorder. The slow protein motions (static disorder) produce slightly different conformations which, in turn, modulate the energy of the exciton-CT states. In this scenario, in some of the LHC/RC complexes within the sample ensemble the energy could be trapped in some unproductive states leading to unacceptable energy losses.

Here I will show that LHCs and RCs have found a unique solution for overcoming this barrier: they use the principles of quantum mechanics to probe many possible pathways at the same time and to select the most efficient one that fits their realization of the disorder. They use electronic coherence for ultrafast energy and electron transfer and have selected specific vibrations to sustain those coherences. In this way photosynthetic energy transfer and charge separation have achieved their amazing efficiency. At the same time these same interactions are used to photoprotect the system against unwanted byproducts of light harvesting and charge separation at high light intensities.

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PS5.3

Shining a new light on the consequences of the ultrastructural organization on the function of bioenergetic electron transfer chains
Fabrice Rappaport
Institut de Biologie Physico-Chimique, UMR 7141, CNRS-UPMC, 13 rue P et M Curie, 75005 Paris, France
E-mail: fabrice.rappaport@ibpc.fr

The structural and functional organization of bioenergetic electron transfer chain has been a matter of long-standing debates with fluctuating outcomes. The solid-state model in which electron transfer occurs within a single supramolecular edifice has been challenged by the random collision model in which the enzymatic activities involved in the chains are borne by individual membrane bound complexes linked by freely diffusing soluble electron carriers. Yet, the beginning of this century saw the revival of the solid-state model with numerous and circumstantial evidences supporting the notion that the structural clustering of the various complexes of the mitochondrial electron transfer chain can shape its function. This reached its acme with the observation that “respirasomes” made of all the enzymes and soluble carriers required to funnel electron transfer from NADH to molecular oxygen do respire and are dynamic structures that determine electron fluxes from different substrates.

Expectedly, similar concepts apply to the photosynthetic electron transfer chain. Protein crowding has been shown to constrain the diffusion of plastoquinone in the thylakoid membrane and of plastocyanin in the lumen. Along similar lines, the dynamic (dis)assembly of supercomplexes that would sequester the soluble carrier, ferredoxin, has provided a tempting model to rationalize the switch between linear and cyclic electron flows. The isolation of supercomplexes comprising photosystem I and cytochrome b6f, has provided support to the notion that the structural remodeling of bioenergetic electron transfer chains can shape their function by (re)routting the electron fluxes.

To widen the spectrum of the methods available to assess the functional relevance of the structural organization of respiratory membranes and provide a new perspective, we recently developed a method aimed at making the respiratory chain amenable to time-resolved studies. In parallel, we identified, in the photosynthetic chain, the parameter that controls the switch between linear and cyclic electron flows and the correlated formation of PSI-b6f supercomplexes. These results will be presented and the overall issue of the functional consequences of the structuration of bioenergetic membranes will be discussed.

References

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P6.1

Engineering the respiratory metabolism of the hyperthermophilic archaeon, Pyrococcus furiosus
Michael W.W. Adams
Department of Biochemistry & Molecular Biology, University of Georgia, Athens, GA 30606, USA
E-mail: adams@bmb.uga.edu

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Michael W.W. Adams
Department of Biochemistry & Molecular Biology, University of Georgia, Athens, GA 30606, USA
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P6 Prokaryotic Bioenergetic Systems

P6.1

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Michael W.W. Adams
Department of Biochemistry & Molecular Biology, University of Georgia, Athens, GA 30606, USA
E-mail: adams@bmb.uga.edu

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