Chapter 5

The Light-Harvesting System of Purple Bacteria

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Summary

Antenna proteins from purple photosynthetic bacteria are by far the best-understood photosynthetic light-harvesting proteins, and among the best-characterized membrane proteins in any biological field. The photosynthetic membrane of purple bacteria is an exceptional case of a membrane for which structural information is available on the partner proteins involved in a biological process. The bacterial light-harvesting system constitutes an ideal source of experimental results for confronting theories to explain the functioning of these biological molecules in elementary physical and chemical terms, and for exploring light capture and transfer mechanisms at the level of the whole membrane. This chapter reviews the different aspects of our current knowledge on light-harvesting proteins from purple bacteria. A special emphasis is given to the biochemical properties of these complexes, their natural diversity, and the details of the known structures. The most recent results on the physical mechanisms that underlie their electronic properties, and on the cascade of the ultrafast excitation transfers that follow the absorption of the solar light are summarized. These are discussed in the light of the different models and calculations that have been performed from the crystal structure.

I. Introduction

Light-Harvesting (LH) proteins from purple bacteria are probably the best-characterized photosynthetic antenna proteins with regard to structure and function and also from a spectroscopic point of view. Actually these proteins are among the best-characterized membrane proteins in any biological field, because they possess a combination of properties that make them particularly attractive for both biochemical and biophysical studies. Firstly, the light-harvesting system from most purple bacteria is comprised of only one or two different membrane protein-pigment complexes. Each of these complexes exhibits characteristic absorption properties, and they are naturally over-expressed in the photosynthetic membranes. In bacterial species that synthesize only one type of antenna complex, the absorption of the whole photosynthetic membrane therefore arises mainly from these pigment-protein complexes. Spectroscopic characterization of these proteins thus was started even before the first protocols to purify them were developed (Thornber, 1970; Clayton and Clayton, 1972). Secondly, the bacteriochlorophyll (BChl) molecules bound to these proteins exhibit absorption properties in the near infrared that are very different from those of isolated BChl, and which depend critically on the type of antenna protein they are bound to. Denaturation of these proteins thus results in a dramatic change in their near infrared absorption spectra. This means that the quality of a preparation may be readily analyzed simply by recording its absorption spectrum. Because of this, biochemical characterization of these proteins was performed in early days of membrane protein biochemistry (for a review see Zuber and Cogdell, 1995), opening the way for a wide range of biophysical studies.

In the photosynthetic purple bacteria, the light-harvesting system generally contains a core antenna, also called LH1, which transfers excitation energy directly to the reaction centers. In BChl a-synthesizing bacteria, LH1 complexes typically absorb at 870–880 nm. Their absorption peak is shifted to about 1000 nm in BChl b-synthesizing species. Many bacterial species also contain peripheral antenna complexes, LH2, which transfer excitation energy to the reaction centers via LH1. LH2 complexes usually exhibit two major absorption transitions in the near infrared, at 800 and 850 nm in BChl a-containing bacteria. The near infrared absorption transitions of both LH1 and LH2 are thus considerably red-shifted relative to the absorption of isolated, monomeric BChl a (770 nm in most organic solvents). In LH complexes, BChl molecules responsible for a given Q absorption transition are usually referred to as B followed by the position of this transition, e.g. B800 or B850 (Fig. 1).

Both LH1 and LH2 are oligomers of an elementary unit, composed of a pair of small (5–7 kDa), very hydrophobic apoproteins, called α and β, each of