Chapter 13

Interactions Between Photosynthesis and Respiration in Facultative Anoxygenic Phototrophs

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Summary

The respiratory and photosynthetic electron transport chains of the two facultative phototrophs *Rhodobacter*
(*Rb.*) *sphaeroides* and *Rb. capsulatus* are arranged in such a way to be spatially segregated in separate regions of the internal membrane system (CM and ICM). The CM part contains the majority of the oxidative redox components which are therefore in redox non-equilibrium with most of the photochemical RCs; conversely, the major part of the photosynthetic carriers (including RCs, Cyt c₂ or Cyt c₁ and Cyt bc, complex) are located in the ICM part of the membrane. This spatial level of organization is paralleled by an arrangement of these photosynthetic elements in supramolecular complexes in order to allow a fast and efficient cyclic electron transfer by limiting the diffusion of the reactants. However, these two levels of arrangement are not present in all types of photosynthetic bacteria. Indeed, species like *Blastochloris viridis* or *Rubrivivax gelatinosus*, contain a large excess of RCs over the Cyt bc₁ complexes so that the formation of supercomplexes is stoichiometrically hindered. Further, in obligate aerobic phototrophs such as for example *Roseobacter denitrificans*,

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the Qa is fully reduced under anaerobic conditions and this might be due to the lack of both quinol oxidase and ICM system.

The expression of photosynthetic and respiratory components is controlled by the oxygen tension and by the redox state of the system. This genetic coordination mechanism does not necessarily require a direct interaction of the two sets of components in line with their different spatial membrane location. The signals to which the system responds originate from either specific respiratory components, e.g. cbb, oxidase, as in the case of oxygen sensing, or from redox carriers involved in both oxidative and photosynthetic ET, as for redox sensing. Although the genetic control of the supramolecular arrangement of the ETCs is, at present, largely undefined, the working scheme presented here, suggests a tentative framework of genetic regulatory connections in Rb. capsulatus and/or Rb. sphaeroides

I. Introduction

A. Background: What Is Important to Know About Physiology, Ecology, and Biochemistry of Facultative Photosynthetic Bacteria

Facultative photosynthetic bacteria are anoxygenic phototrophs, i.e. do not generate oxygen during their photosynthetic growth as Cyanobacteria do (see Chapter 12 by G. Schmetterer, Vol. 2), which are also capable to obtain energy from aerobic and anaerobic metabolism in darkness (Prince, 1990; Zannoni, 1995). In general, their photosynthetic apparatus (bacteriochlorophylls and carotenoids of light-harvesting systems, photochemical reaction center) is strongly repressed by molecular oxygen (Drews and Golecki, 1995); an exception to this rule, is a group of bacteria, the so called ‘aerobic anoxygenic phototrophs’ primarily isolated from marine environments (genera: Erythrobacter and Roseobacter), which are unable to synthesize their photosynthetic apparatus without the presence of molecular oxygen (Shimada, 1995; Yurkov and Beatty, 1998). The metabolic options available to typical facultative phototrophic bacteria, e.g. genera Rhodobacter, Rhodofex, Rhodopseudalteromonas, put them in a position to survive in quite different habitats and many species can use a variety of carbon sources such as organic acids or fatty acids but also CO₂ as sole carbon source and H₂ as sole electron donor. Facultative phototrophs can be found in natural habitats just below the oxic-anoxic interface of lakes and the capacity to grow in the dark by respiration is generally considered a mechanism for temporary survival in transiently oxygenated environments or as a way for maintaining the energy/redox balance (Madigan, 1988). This latter requirement is however the ‘pre-requisite’ for growth in the case of aerobic anoxygenic phototrophs (Yurkov and Beatty, 1998).

On a physiological/ecological point of view (Trüper and Pfennig, 1982), all anoxygenic phototrophs can be divided into four subgroups: (a) Purple sulfur (Chromatiaceae, Ectothiorhodospiraceae); (b) Purple nonsulfur (Rhodospirillaceae); (c) Green sulfur (Chlorobiaceae), and (d) Green gliding bacteria (Chloroflexaceae). These subgroups do not include strictly anaerobic spore-forming phototrophs of the genus Helio bacterium (Gest and Fawinger, 1983) which are allocated apart (order Clostridiales) due to their physiological peculiarities, e.g. presence of bacteriochlorophyll g (Brochmann and Lipinski, 1983).

On a phylogenetic basis (16S rRNA analyses) purple bacteria and their relatives are grouped in a new class, the Proteobacteria (Stackebrandt et al., 1988) which is formed by several subclasses, namely: α subclass, containing most of the species of the Rhodospirillaceae family along with strictly aerobic species of the genera Erythrobacter; β subclass, including nonsulfur purple genera such as Rhodocyclus and Rubrivivax; γ subclass, which includes purple sulfur bacteria (Chromatiaceae and Ectothiorhodospiraceae). Green sulfur (Chlorobiaceae) and nonsulfur bacteria (Chloroflexaceae), resulted to be phylogenetically unrelated, form two distinct classes (Woese, 1987).

Before going into details about the metabolic