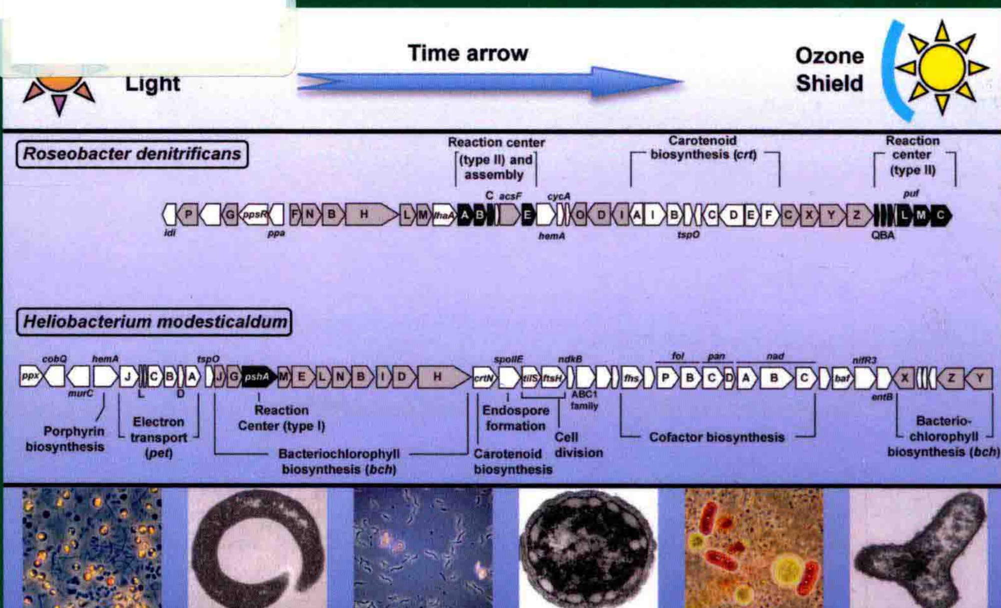
Advances in BOTANICAL RESEARCH

GENOME EVOLUTION OF PHOTOSYNTHETIC BACTERIA



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Genome Evolution of Photosynthetic Bacteria

Volume Editor

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PREFACE

The best evidence indicates that biological photosynthesis arose on Earth more than 3.5 × 109 years before the present, and that the earliest photosynthetic system was anoxygenic, meaning that the photochemical process did not split water (Blankenship, 2010). The bacterial subjects of the chapters in this book perform anoxygenic photochemistries, catalysed by evolutionarily related pigment–protein complexes called reaction centres. Although the most rigorous definition of the word 'photosynthesis' means harvesting of light energy to synthesise organic carbon from carbon dioxide, this word is commonly used to generally describe chlorophyll-based processes that drive electron transfer reactions in living cells. The term 'phototrophy' is sometimes favoured as a general descriptor of the harvesting of light energy, to include organisms such as the aerobic anoxygenic phototrophic bacteria that synthesise little organic carbon from carbon dioxide. However, there are also phototrophs that contain rhodopsin-related pigments, not chlorophyll, and use light energy to drive proton transport pathways directly. Finally, the term 'photosynthetic bacteria' has been used for more than half a century to describe anoxygenic phototrophs that use chlorophylls to harvest light, sometimes referred to as purple or green (phototrophic or photosynthetic) bacteria. These considerations led to the compromise represented by the title of this book, *Genome Evolution of Photosynthetic Bacteria*. Because of the variety of terms used in the literature, contributors were free to wander between the photosynthetic/phototrophic terminology, and so the reader should keep this flexibility in mind when reading the chapters in this volume.

The contributions to this book review data ranging from fossil evidence through genomes of classes or physiological groups of existing organisms, to studies of particular types of proteins, metabolic processes, and cellular responses to environmental cues. Some details may appear to be in conflict because different approaches or interpretations may lead to different conclusions, but such differences are thought to reflect the vibrant, active nature of evolutionary research.

The first chapter (Mulkidjanian & Galperin, 2013) uses a broad brush to start before biological photosynthesis, by reviewing the evidence for abiogenic photosynthesis, and moving on to use gene sequences to suggest a geochemical context for the evolution of photosynthesis genes in six key bacterial phyla. In Chapter 2, Gupta (2013) uses his original gene insert/deletion (indel) analysis of sequences to arrive at plausible origins of photosynthesis genes.

The Heliobacterial genome is evaluated by Sattley and Swingley (2013) in Chapter 3, and Bryant and Liu (2013) provide a wide-ranging coverage of members of the phylum Chlorobi in Chapter 4, and delve deeply into evolutionary scenarios relating to the origins of pigment biosynthesis and reaction centre genes.

The so-called purple bacteria are the focus of the remaining chapters. Nagashima and Nagashima (2013) compare photosynthesis gene clusters and evaluate the likelihood of horizontal gene transfer in Chapter 5. In Chapter 6, Gomelsky and Zeilstra-Ryalls (2013) describe changes in the genome-wide transcriptome of *Rhodobacter sphaeroides* in response to changes in the concentration of molecular oxygen and light intensity. The evolutionary history of light-harvesting genes is deciphered by Henry and Cogdell (2013) in Chapter 7, and Willison and Magnin (2013) review the function and evolution of endogenous plasmids in Chapter 8. The evolution of bacteriophytochromes is the focus of Papiz and Bellini's (2013) Chapter 9, whereas in Chapter 10, Zappa and Bauer (2013) analyse three *Rhodobacter* genomes to deduce strategies for maintaining iron homeostasis.

The last three chapters are devoted to the interesting group of purple bacteria known as the aerobic anoxygenic phototrophs. Yurkov and Hughes (2013) provide a broad introduction to the group in Chapter 11, and in Chapter 12, Zheng, Koblížek, Beatty, and Jiao (2013) use genome sequences to suggest that photosynthesis genes have been acquired by horizontal gene transfer in one species, and lost from the phototrophic ancestor of a present-day chemotroph. In the final chapter, Koblížek, Zeng, Horák, and Oborník (2013) perform an extensive analysis of the genomes of several members of the *Roseobacter* clade, and conclude that in progenitors of these species there has been regressive loss of carbon dioxide fixation genes, followed by loss of photosynthesis genes, in pathways leading from photoautotrophs through photoheterotrophs to chemoheterotrophs.

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CONTENTS

CHAPTER ONE

A Time to Scatter Genes and a Time to Gather Them: Evolution of Photosynthesis Genes in Bacteria

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Contents

Abstract

Genome sequencing opened entirely new avenues for studying the evolution of photosynthesis. By systematically comparing sequences of photosynthesis-related genes and their products in phototrophic members of diverse bacterial lineages, it has become possible to delineate their common and distinct traits, analyse their evolutionary relationships, and reconstruct the likely scenarios for the overall evolution of the photosynthetic machinery. We consider here the comparative genomics data on the distribution of photosynthesis genes among certain representatives of six bacterial phyla, (Acidobacteria, Chlorobi, Chloroflexi, Cyanobacteria, Firmicutes, and Proteobacteria) and put these data in a broader geochemical context. We address the tentative nature of the first photosynthetic organisms, the driving forces behind their origin, and review the evidence for the early origin of abiogenic photosynthesis.

1. INTRODUCTION

Photosynthesis is a key biological process that may have emerged even before the origin of life on the Earth and played a key role in shaping the

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