Preface

This book presents bacteria in a different way from classic texts of microbiology such as Bergey's manual, focusing on their functional properties and how they evolved along phylogeny. Paramount among the functional properties is the capacity of bacteria to extract bioenergy from their environment, from simple elements such as sulfur and iron to complex biopolymers such as chitin and cellulose. This capacity is usually referred to as central metabolism, which depends upon diverse electron transport systems that generate bioenergy by transporting protons across the cell membrane while transferring electrons from environmental donors to acceptors of various kinds. The core of bacterial life and survival thus resides on the genomic endowment of bioenergy-producing systems that cumulatively form the respiratory chain and define the bioenergetics of prokaryotes.

Respiration consists of reducing oxygen with electrons, a process that is chemically equivalent to the reduction of a variety of electron acceptors such as nitrate and sulfate, which are exploited by bacteria when oxygen is scarce or missing. Such redox processes are still defined as respiratory, since they are based upon the reduction of a terminal acceptor available from the environment like oxygen. However, bacteria evolved long before the current levels of ambient oxygen were established about two billion years ago; before that time, hydrogen, sulfur and reduced metals like Fe^{II} were most abundant. Ancestral bacteria exploited these elements in developing their bioenergy production machinery to survive and thrive with specialized, anaerobic respiratory chains. Many microbes that will be presented in this book have maintained such anaerobic respiratory chains even if they have become aerotolerant, or facultatively aerobic after oxygen reached today's levels in earth habitats. In practice, you cannot recognize bacteria that have different physiology, for example facultatively anaerobes and obligate aerobes, on the basis of their morphology, or even from their marker RNA gene—the molecular tool which has become the benchmark for bacterial classification. You can only distinguish them from the functional properties that you measure with microbiological and biochemical methods, or deduce from the genomic features that determine such properties. This book will present the core functional properties that distinguish various types of Gram negative bacteria, from the most ancestral with anaerobic respiratory chains to the progenitors of the aerobic mitochondrial organelles of our cells. Mitochondria derive from a particular brand of extinct bacteria whose identity, and relationship with extant bacteria, is beginning to emerge from the integration of genomic and functional analysis with molecular phylogeny, as will be discussed in the last two chapters of the book.

Writing the initial chapters of the book gradually unveiled the underlying thread of entwined function and phylogeny that links very diverse bacteria such as Bacteroidetes from our oral microbiota, predatory Myxobacteria in the soil and alphaproteobacteria forming symbiotic associations with plant roots. Fundamental bioenergy-producing redox systems have been inherited from phylogenetically ancient Bacteriodetes to plant symbionts producing functionally equivalent respiratory chains, despite enormous differences in microbiological characters and taxonomic classification. Ultimately, function has been conserved along evolution much more than the individual genes of bacteria and their characters that we can empirically evaluate, also in phylogenetic terms. This book then offers a new fascinating perspective to look at bacteria through the angle of their functional inheritance that evolved along billions of years, which we can now discern by genomic analysis. In this perspective, we shall also discover the living bacterial relatives of our mitochondria. Indeed, paraphrasing Woese (1987), bacterial evolution holds the key to the origin of the eukaryotic cell, which is deeply interconnected with the acquisition of mitochondria.

Although the initial idea for this book was to have several scientists contributing a chapter on their area of expertise, at the end I preferred to write multiple chapters myself. I am very grateful to Bill Martin, who has written the first, breathtaking chapter on the origin of bacterial life and physiology, to Esperanza Martinez-Romero, who has been so kind to help me writing three chapters, and also Paola Bonfante, who has contributed an incisive and informative part to chapter six. I also thank other co-authors and colleagues who have variably contributed to chapters of this book, which hopefully will constitute a reference source of information, and inspiration, for scientists interested on how bacteria evolved into the mitochondria of our cells.

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