Preface

This book is an attempt to meld together theory and experiment in a fundamental aspect of protein biology. Electron transfer reactions are essential for life. Not only do they provide the means for harnessing solar energy and transforming the chemical energy of foodstuffs into a readily utilizable form, they also extend into a range of metabolic processes that support the life of the cell. They are the simplest of chemical reactions in that they do not normally involve the making or breaking of bonds, but on the other hand proteins are necessary to control the rates and this imposes a degree of complexity. Chemical reactions are strongly localized in space, but electron transfer between the metal centres on which an electron might reside in a protein can take place over distances many times larger than the length of a chemical bond. Sometimes, as in photosynthetic reaction centres, the reaction does not show the usual Arrhenius type of temperature dependence. For example, in *Rhodobacter sphaeroides*, the rate constant for electron transfer from the excited special pair to bacteriophaeophytin *decreases* as the temperature *increases.* Even more remarkable is the fact that site-directed mutagenesis of a single residue (Tyr-M210) can drastically modify this unusual temperature response. How is such behaviour to be explained?

The basic questions, then, are: what are the physical factors that determine the rate constants for protein electron transfer? How do protein structure, and the structure of the redox centre itself, influence these factors? The proteins concerned may either be organized into a larger complex or interact by diffusion and collision. In the former case the protein acts as a scaffold on which to hang two or more redox groups. In the latter, the proteins will have to seek out an appropriate configuration of a short-lived collision complex, and the nature of the forces concerned poses an additional question. Physical theory can now provide an understanding of electron transfer at a level which is sufficiently explicit and detailed to guide experimentation by those attempting to understand the structural basis of the properties of particular systems.

The subject is not the organization of electron transport chains, but what determines the underlying rate constants. The unusual feature of this book for biochemists is that it involves the explicit application of quantum mechanics to biological behaviour. This may appear daunting at first sight, but the spirit of the book is that this need not be so. Quantum-mechanical tunnelling is shown to have predictive power in biology, and an ability to explain otherwise puzzling phenomena. The chapters are arranged in such a way that different aspects of the theory of electron transfer are introduced first in a manner which places the emphasis on concrete physical understanding rather than mathematical rigour. The more mathematical aspects of the subject are reserved for two appendices. The aim has been to take theory and experiment together to develop a framework of ideas that can be applied to a variety of systems. This is the concern of the first four chapters. The fifth discusses the crystal structures of electron transfer proteins and complexes; it forms an essential bridge between the general and the particular because true understanding at the molecular level is dependent on detailed structural information. In the next four chapters the most thoroughly investigated systems, grouped under the main classes of redox protein, are discussed as tests of the theory. First and foremost is the photosynthetic reaction centre of purple bacteria; other chapters discuss copper proteins and haem proteins before the final topic of linkage between electron transfer and proton translocation in complexes such as cytochrome oxidase is tackled.

If the problems of biological electron transfer can now be perceived with a degree of clarity, it is due as much to the participation of chemists and physicists as of biologists. The complexities of biological systems for long clouded the issues. The old arguments about the nature of biological oxidations were not completely resolved by Keilin's discovery of cytochromes and his concept of a respiratory chain. For a long time it was unclear whether the cytochrome system was a chain of electron carriers or of hydrogen carriers, although the chemiosmostic hypothesis took advantage of this uncertainty. The basic question of how a series of protein carriers could operate in a chain was not resolved until it was established that electron transfer could take place at reasonable rates over a distance of 10–20 Å through a protein. Chemists were able to avoid these difficulties by at first tackling the simpler cases of small metal complexes, both experimentally and theoretically. The outstanding contribution to the theory of electron transfer in such chemical systems was made by R.A. Marcus, starting in the late 1950s. Later it appeared that biological systems could also be brought into the same theoretical framework and the review on electron transfers in chemistry and biology by Marcus and Sutin, published in 1985, represents a milestone in the development of the subject. It is appropriate that the last chapter of the book is Marcus's own account of how the subject of electron transfer developed and is still developing, and it opens several windows on to areas of interest which are beyond the scope of this book.

In the 1990s it seems that research on electron transfer in proteins has entered its exponential phase of growth. This book is a collaborative effort, made possible by the willingness of a group of leading figures in the subject to write about their own areas of expertise. It has been planned primarily with the needs of biochemists in mind, in the hope that it will aid those who wish to understand the structural and physical basis of particular electron transfer systems and plan their own experiments; it should also be of value for graduate students and advanced undergraduates.

D.S. Bendall (*Cambridge, UK*)