

# Preface

Recent evidence suggests that quantum mechanics is relevant in photosynthesis, magnetoreception, enzymatic catalytic reactions, olfactory reception, photoreception, genetics, electron transfer in proteins, and evolution, to mention a few. It has become evident that certain organisms can harness some of the quantum-mechanical features for a biological advantage over competitors. On the other hand, the standard DNA template-replication paradigm is not able to explain neither the long-term storage of the genetic information nor the evolution of genetic material through generations. Classical/quantum information theory provides the limits, known as channel capacity, beyond biological errors that cannot be corrected for. Any correction mechanism in communication systems has the limits on error correction capability. The DNA pol proofreading and DNA repair mechanisms are weak error correction concepts, far away from biological channel capacity, and as such are unable to explain the faithful preservation of the genetic information through the ages. The concepts from unequal error protection must be used to explain the faithful preservations of important genes through generations. However, this genetic stability is not absolute, regardless of genetic error correction mechanism. On the other hand, the imperfect stability in genetic material is also responsible for evolution. Without evolution, life will be in the same form as it initially appeared. There were also many attempts in an effort to explain the structure of genetic code and transfer of information from DNA to protein by using the concepts of classical information theory. However, given that many biological processes in organisms are quantum mechanics dependent, classical information theory is insufficient to provide proper answers to many open problems today. Moreover, given that Shannon (classical) entropy is just the special case of von Neumann (quantum) entropy, it appears that only quantum information theory efforts are relevant.

The key idea in this book is to describe various biological processes as communication processes, be they of classical, quantum, or hybrid nature. By using this approach, we describe the information flow from DNA to protein as the quantum communication channel problem. In this model, DNA replication, DNA to mRNA transcription, and mRNA to protein translations are considered as imperfect

processes subject to biological errors. We employ this model to describe both faithful preservation of genetic information and the evolution of genetic information from generation to generation. We then establish the connection between operator sum representation, used to model quantum biological channels, and quantum master equation (QME), widely used in quantum biology to describe various processes listed above, in particular photosynthesis, magnetoreception, and photoreception, and demonstrate that QME is just the Markovian approximation of the operator sum representation. This indicates that the quantum channel model description given by operator sum representation and the QME description are equivalent to each other (under the Markovian approximation) and can be interchangeably used to simplify the description of quantum biological process. The particular use of representation is dictated by the biological problem at hand. Therefore, our approach essentially integrates quantum information theory (QIT) and currently existing quantum biology (QB) approaches, and as such it can be called the *quantum biological information theory*.

The book *Quantum Biological Information Theory* is a self-contained, tutorial-based introduction to quantum information theory and quantum biology. It serves as a single-source reference to the topic for researchers in bioengineering, communications engineering, electrical engineering, applied mathematics, biology, computer science, and physics. The book provides all the essential principles of the quantum biological information theory required to describe the quantum information transfer from DNA to proteins, the sources of genetic noise and genetic errors, as well as their effects. For additional details on the book, an interested reader is referred to the introduction chapter and contents.

The unique features of the book include:

- It integrates quantum information and quantum biology concepts.
- The book does not require the prior knowledge of quantum mechanics.
- The book does not require any prerequisite material except basic concepts of vector algebra at undergraduate level.
- The book does not require prior knowledge in genetics or cell biology.
- This book offers in-depth discussion of the quantum biological channel modeling, quantum biological channel capacity calculation, quantum models of aging, quantum models of evolution, quantum models on tumor and cancer development, quantum modeling of bird navigation compass, quantum aspects of photosynthesis, and quantum biological error correction.
- The successful reader of the book will be well prepared for further study in this area and will be qualified to perform independent research.

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Djordjevic, I.B.

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