Preface

"... for utterly impossible as are all these events they are probably as like those which may have taken place as any others"

— **James Joyce, *Finnegans Wake* (1939)**

There have been many attempts to answer what is perhaps the most fundamental question in biology—how did life evolve? None has been entirely successful. This book is no exception. The story line presented here is incomplete and subject to criticism. This is expected. By their very nature, fundamental questions deal with complex issues, and it is fair to say that life as we know it is extraordinarily intricate. The challenge of answering how life evolved faces an additional difficulty. Life emerged from inanimate matter. Its origins, therefore, must be found in chemistry and physics, which are equally complex subjects. This compounds the difficulty of uncovering life's origins. Yet an answer must exist, and any effort to seek it out, even if necessarily incomplete, is potentially worthwhile.

The approach taken in this book is also not unique. Every attempt to understand how life evolved has rested on the fundamental principles of chemistry and physics and the language of mathematics. This book is no exception. Every sensible theory to explain a more complex phenomenon must ultimately be based on first principles describing simpler systems and, at the same time, it must be consistent with the behavior of the complex phenomenon the theory attempts to explain. The same is true for any theory about the origins of life. Fortunately, we have knowledge about fundamental chemical and physical processes—from the nature of covalent bonds and passive diffusion to surface tension and nonequilibrium thermodynamics—that permits the construction of a theory about the origins of life based on first principles. However, we also have knowledge about modern-day organisms (e.g., how cells metabolize, grow, and divide), which can also guide our understanding of how life began and evolved. Therefore, the approach taken in this book is to construct a plausible, integrated theory about how life evolved using both a bottom-up and a top-down approach.

Arguably what makes this book different from other narratives is the degree to which first principles are pedagogically explained and then used to move the narrative along. The goal here is to be instructive as well as informative. At each critical point in this book's story line, the pertinent principle or principles are explored so that their importance and relevancy are made clear. In this way, the reader is sufficiently informed to either accept or reject where and how the overall narrative is going.

This approach also helps to identify the book's intended audience. It is written for the classroom to show students how the physical sciences help us understand biology. In a very real sense, this book has two goals. The first is to explore how life evolved and to show that biology, chemistry, and physics are inextricably linked.

The second goal is to inspire contemplation and debate within the classroom. If we seek life's origins, we must also ask other equally challenging questions. For example, what do we mean by saying something is alive? What do we mean by the words *gene*, *genome*, or *inheritance*? These and other questions are explored, but not without difficulty and debate because their answers depend on where we are in the narrative of life's origins. To this end, each chapter concludes with suggested readings (mostly from the older literature, which is often forgotten or ignored) and one or more discussion questions (intended to draw attention to key points or problems within the book's narrative).

A few words about organization. The book has nine chapters and an introduction. The first four chapters set the stage for what follows. The chapters should be read in sequence. Each builds on what precedes it and sets the stage for what follows. The book's central thesis starts in Chapter 5. It is here that the RNA World Hypothesis is introduced and judged to be the most reasonable when compared to alternative scenarios for life's origins. It is also here that molecular selection takes hold for the first time and where physicochemical selection takes a back seat. In comparison to organismic (Darwinian) selection, these two modes of selection may be unfamiliar to some readers. But their difference and importance will become clear.

This book is intended to provide an integrated perspective on the origins of life beginning with the earliest abiotic chemistry and concluding with the first cells (and what followed). Like all such books, there is at best sketchy evidence to support the hypotheses presented. It is our hope that it inspires criticism and by so doing advances our understanding of how life evolved—indeed, even for what it means to be alive.

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February 2024, Ithaca, NY