
Preface

As with the first edition of this book, it was written with students in mind. It is meant to introduce the major topics of molecular evolution in a way that will encourage students to delve deeper into each of the topics. The book started as a series of notes, overheads, and digital slides that comprised a course in molecular evolution. The course was designed as an integrated approach to this field, for which there was no single textbook available. It draws from concepts in evolution, geology, chemistry, biochemistry, molecular biology, genetics, taxonomy, bioinformatics, various OMICS fields, and, of course, molecular evolution. Because it discusses aspects of each of these disciplines, students with broad backgrounds (as well as those with very focused backgrounds) should be able to grasp the concepts, principles, and details of this book. It presents some of the usual information regarding various aspects of cell function, but also details the variety of mechanisms that have evolved. This has been done to present a broader view of evolution that is meant to show that some processes have been approached in very different ways by the diversity of species during their evolution on Earth.

Although the first edition was organized into 18 chapters, including 197 figures, the second edition has been substantially expanded into 34 chapters, with 413 figures, essentially doubling the size of the first edition. It has been divided into six sections. Section I, *Life and Evolution*, covers the topics of evolution on Earth, prebiotic production of organic molecules, and definitions of life. Section II, *Biomolecules*, details the structures and functions of biological molecules, as well as the basic mechanisms that produce the molecules. Section III, *Genetics*, presents the basic genetic mechanisms that lead to the evolution of genomes and organisms. Section IV, *Multicellularity*, outlines the basic mechanisms of cell-to-cell communications and other processes that have led to the evolution of developmental processes in multicellular organisms. Section V, *Molecular Biology and Bioinformatic Methods*, consists of overviews of some of the methods used in molecular biological and bioinformatics research. Section VI, *Genomes*, is a survey of a set of genomes that represents a compendium of some of the important aspects of the evolution of genomes, in general.

Chapters 1 through 5 (included in Sections I and II) are nearly identical to the first five chapters in the first edition. Chapter 1 is an overview of life on Earth, as well as the possible origins of life. The definitions of life are discussed in detail. At the end of the chapter, there is an exercise designed to help the reader imagine and visualize the components of a cell in their true dimensions. Chapter 2 details the evolution of organisms on Earth. It also presents a history of the study of evolution. Chapter 3 covers the basic structures of DNA, RNA, proteins, and other biological molecules, and the syntheses of each. Chapter 4 begins with the central dogma of molecular biology, but then goes into detail about the complexities of all of the central processes of this basic principle. Chapter 5 discusses the largest ribozyme in the cell, the ribosome. This includes details about the structure and function of ribosomes, as well as a discussion about its evolution. Also discussed are the mechanisms for assuring that enough rRNA is produced to supply each cell with all of the ribosomes they need. Ribosomes have been one of the key structures in cells that have led to the success of life on Earth. The remainder of Section II includes Chapters 6 through 8. Chapter 6 is new, although it was partly covered in chapter 5 of the first edition. The new chapter details some of the recent research into the origin of ribosomes, translation, and the genetic code. Conceptually, this might be one of the more difficult to understand chapters, because an alternative organization of the universal genetic code table is presented, which is organized according to the possible evolutionary events that led to translation and the current genetic code. Although the genetic code table that has been used for several decades is informative and useful, it may not reflect the evolution of the genetic code itself. Alternative tables may more accurately reflect the evolution of the genetic code. Chapter 7 discusses the various forms of DNA replication, and how they have been important in evolution. Chapter 8 presents the common, as well as many of the

uncommon, modes of separating chromosomes, from separation of chromosomes in bacteria to mitosis and meiosis in a variety of eukaryotes.

Section III includes three new chapters on genetic mechanisms. Chapter 9 is focused on Mendelian genetic mechanisms, as well as non-Mendelian mechanisms of inheritance. Chapter 10 discusses the basic concepts of population genetics, including Hardy-Weineberg equilibria, population size, life histories, and modes of reproduction, all of which affect allele proportions in populations. Chapter 11 further details some of the phenomena that affect allelic proportions in populations through time, including natural selection, random genetic drift, mating and dispersal, and gene flow. Chapters 12 and 13 present the major causes and mechanisms of mutation, including repair of mutations. These were chapters 8 and 9 in the first edition.

Section IV includes one of the first edition chapters (Chapter 11 on multigene families), which is now Chapter 14 in this second edition. The other four chapters in this section are new. Chapter 15 details horizontal gene transfers (HGTs) that occur very often, and they have been occurring for billions of years. Chapter 16 begins a discussion of development, which depends on coordinated cell-to-cell communication and precise programming of gene expression in each cell. This chapter includes details regarding quorum sensing in bacteria and development in animals. Chapter 17 continues with the details of development in higher plants. Chapter 18 is focused on the genetic changes and mechanisms in carcinogenesis. Some of the same mechanisms that cause evolutionary changes are the same mechanisms that cause cancer.

Section V outlines some of the basic methods used to study molecular evolutionary processes. Chapter 19 explains some of the methods for purifying and quantifying nucleic acids and proteins. Chapter 20 presents some of the basic recombinant and characterization methods used in molecular evolutionary studies. Chapter 21 details the various methods of sequencing of DNA (and cDNA from RNA), as well as proteins. Chapters 22 and 23 are surveys of various OMIC methods to analyze DNA, RNA, protein, and other molecular data. Chapter 24, *Species Concepts and Phylogenetics*, is an amalgamation of two of the first edition chapters (Chapters 10 and 12). This seemed to be a logical combination. Chapter 25, *Phylogenetic Networks and Reticulate Evolution*, is new in this second edition. It outlines evolutionary processes that are beyond simple bifurcating trees and events (e.g., HGTs—described in Chapter 15), and explains how they are determined. Chapter 26, *Phylogenomics and Comparative Genomics*, explains some of the processes and challenges in using genomic data in genomic studies of evolutionary processes.

The final section, Section VI, describes specific genomes. Each has been chosen either as a representative of a specific taxonomic group, or to illustrate one or more principles of the processes that occur during the evolution of the species and their genomes. Chapters 27 (RNA Viruses), 28 (DNA Viruses), 29 (Bacteria and Archaea), 30 (Mutualists and Pathogens), and 31 (Endosymbionts and Organelles) parallel Chapters 13 through 17 of the first edition. Chapter 32 is new. Its focus is on protein trafficking in cells. It begins with trafficking in bacteria, and proceeds into more complex trafficking in Eukarya. Chapter 33, *Eukaryotic Genomes*, has been edited, including the deletion of the human genome. Discussion of the human genome has been expanded in Chapter 34. Part of the additions to this chapter includes details about how the human genome has led to some practical applications of the information.

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