INTRODUCTION

"Unless such [profitable genetic variations] occur, natural selection can do nothing."[1]

—Charles Darwin

Darwin knew that changes in heritable matter—which today we call genetics—were essential to evolution. The divergence of reptiles, birds, mammals, plants, and every other species must be underwritten by new, beneficial genetic changes. But Darwin didn't know what caused them: "I have hitherto sometimes spoken as if the variations—so common and multiform with organic beings under domestication, and in a lesser degree with those under nature—were due to chance. This, of course, is a wholly incorrect expression, but it serves to acknowledge plainly our ignorance of the cause of each particular variation." (Darwin 1952a, p. 65).

Since the neo-Darwinian synthesis in the middle of the twentieth century, evolutionary biology has suffered no similar doubt. Genetic variation is said to be caused by random mutations, with particular emphasis on point mutations—changes in individual alleles that code for specific traits.

One purpose of this book is to demonstrate that the doctrine of chance mutation is false. A second purpose is to demonstrate the falsity of related neo-Darwinian doctrines: the population genetics models that have been built upon Mendelian genetics. In short, the objective is to cast off neo-Darwinism altogether.

A third purpose is to demonstrate that significant genetic variation—the kind of variation necessary for evolution—occurs as rearrangements of DNA sequences through transpositions, translocations, insertions, inversions, splicing, deletions, additions, amplifications, and duplications. Much DNA, including that which is rearranged, does not code for specific traits or even specific proteins. Rather, it regulates the developmental sequences of organisms. Genetic rearrangements alter the developmental sequences. These can result in minor changes in specific traits, but they also can result in cascades that affect suites of traits or alter overall morphology.

The hypothesis that significant variations are due to genetic rearrangements is not new. It is fairly well-accepted among biologists, especially molecular geneticists and developmental biologists. What is new, or is at least more greatly amplified in this book, is that evolution through genetic rearrangement is utterly inconsistent with the neo-

[1] Darwin 1952a, p. 41.

Darwinian synthesis.

The fourth and ultimate purpose is to solve the puzzle of sex and conjugation. By "sex" I mean the effects of three genetic manipulations that occur during the process leading to reproduction: a) the event known as "crossing-over," which occurs during meiosis I, when homologous chromosomes transfer and reorganize DNA; b) the event that occurs during meiosis II, when chromosomes are recombined into new, unique haploid combinations in gametes (sperm and unfertilized eggs); and c) when gametes unite, which results in a new, unique combination of diploid chromosomes. By "conjugation" I mean the process that occurs in "lower" organisms when they donate or swap DNA, separate from the act of reproduction.

Sex has long been a difficult problem for neo-Darwinian theory: "The existence of sexual reproduction poses a big theoretical puzzle to Darwinians." (Dawkins 1986, p. 268). Although in some species, such as our own, sex is necessary for reproduction, that is not its adaptive function. Many lower organisms reproduce asexually (cloning). In many of these species, organisms switch to sexual reproduction at some stage in their life cycles. There are species, such as dandelions, that have even reverted from sexual reproduction to asexual. If reproduction were the function of sex, cloning would be far simpler, more efficient, and wouldn't require males. Moreover, even in species in which reproduction is tied to sex, reproduction itself doesn't explain the genetic manipulations that accompany sex, including the intricate molecular processes involved in meiosis and crossing-over. Furthermore, conjugation, which like sex involves genetic manipulations in the transfer of DNA, occurs separate from reproduction.

That sex is a puzzle should be embarrassing for evolutionary biology. Sex must be extremely important. Most organisms reproduce sexually at some point in their life cycles. Sexual reproduction is present in all taxa and most species. No known "higher" organisms have evolved through cloning. All either reproduce sexually (at least periodically) or have evolved from ancestors that did. (Bell 1982, p. 437; Maynard Smith and Szathmary 1995, pp. 164-66). As the study of microorganisms has progressed, it is no longer even clear that any lower organisms have evolved by cloning, since they engage in conjugation.

Not only should it be embarrassing, the fact that sex remains a puzzle should be a clue that something fundamental is wrong with the whole neo-Darwinian framework. A leading theorist on the subject, John Maynard Smith, once remarked that "[o]ne is left with feeling that some essential feature of the situation is being overlooked." (Ridley 1993, pp. 40-41, quoting Smith). The essential feature that has been overlooked, which Maynard Smith did not consider, is that the population genetics model and the concept of chance mutation are wrong. After describing sex as inconsistent with evolutionary theory, Williams stated that his "purpose is to propose minimal modifications of the theory to account for" sex. (Williams 1975, Preface, v). The argument that follows is

that sex can't be solved with minimal modifications to neo-Darwinism; neo-Darwinian theory needs radical surgery, including removal of the concepts at its core.

The hypothesis set forth in this book is that genetic rearrangements are not due to "mutations" in the sense of random errors. Rather, they are produced by experimental genetic tinkering. This is the adaptive function of sex in higher organisms. It is also the adaptive function of conjugation in lower organisms.