Preface

This book explores the interplay between learning and evolution in the context of linguistic systems. For several decades now, the process of language acquisition has been conceptualized as a procedure that maps linguistic experience onto linguistic knowledge. If linguistic knowledge is characterized in computational terms as a formal grammar and the mapping procedure is algorithmic, this conceptualization admits computational and mathematical modes of inquiry into language learning. Indeed, such a view is implicit in most modern approaches to the subject in linguistics, cognitive science, and artificial intelligence.

Learning (acquisition) is the mechanism by which language is transmitted from old speakers to new. Therefore, the evolution of language over generational time in linguistic populations will depend upon the learning procedure used by the individuals in it. Yet the interplay between learning by the individual and evolution of the population can be quite subtle. We need tools to reason about the phenomena and elucidate the precise nature of the relationships involved. To this end, this book presents a framework in which to conduct such an analysis.

Most people can directly observe the learning of language by children and marvel at the phenomenon of language acquisition. In contrast, few people have direct experience with the unfolding history of a language. Picking up an Old English text like the Anglo-Saxon Chronicles is not always part of our daily existence. People doing this, however, will find a language that is incomprehensible to modern English speakers. This leads to the following question: if in the ninth century A.D., people in England spoke a language like that in the Anglo-Saxon Chronicles, this is the language their children should have learned — and their children after them, and so on. How, then, did it come to be that the process of iterative learning by successive generations led to the evolution of English so far from its origins? What does it imply for how English might be a thousand years from now?

Of course, the problem is not limited to English alone. Language change
and evolution is ubiquitous. It happens in most languages, in their syntax, their phonology, and their lexicon. It manifests itself in language birth and death phenomena, in creolization, and in dialect formation. It is happening around us as we speak. More mysteriously, it has happened over evolutionary time scales as the language capacity evolved from prelinguistic versions of it.

There is thus a tension between language learning and language evolution. On the one hand, the learning of language by children is robust and reliable. On the other hand, it cannot be perfect or else languages (barring major migratory effects) would not change. This book is an attempt to resolve this tension.

The analytic framework introduced here considers a population of linguistic agents. Linguistic agents are of two types: mature users of a language and learners who acquire a language from the other users. Each learner acquires language based on its own primary linguistic data, i.e., linguistic examples received from other users in the community. By taking an ensemble average across learners, we can derive the average linguistic composition of the mature speakers of the next generation. Thus the average linguistic composition evolves as a dynamical system. The framework is noteworthy for its shift of emphasis from the individual to the population in the analysis of learning and its evolutionary consequences. Much of language learning theory (often termed learnability theory) focuses on an idealized speaker-hearer interaction in a homogeneous linguistic environment. In this tradition, one is concerned with whether the learner will converge to the unique target grammar of the parent as more and more data becomes available. In contrast, I analyze learning algorithms in the case in which the learner is immersed in a heterogeneous linguistic environment. There is no unique target grammar and the learner never converges. Instead, there is a distribution of grammars in the linguistically mature population, and the learner matures after a finite time corresponding to its developmental learning period.

In this setting, my main results may be summarized as follows. First, I elucidate the subtle nature of the relationship between learning and evolution. In particular, I show that different learning algorithms may have different evolutionary consequences. Therefore, we are able to bring to bear both developmental and evolutionary data and arguments to judge the plausibility of various learning algorithms for language acquisition. Second, I find that the dynamics of language evolution are typically nonlinear. Further, there are often bifurcations that lead to a change in the stability profile of the equilibrium distribution of languages. The parameters associated with such bifurcations are naturally interpretable as the frequency of usage of
various linguistic expressions. Thus, much like phase transitions in physics, I argue that the continuous drift of such frequency effects could lead to discontinuous changes in the stability of languages over time. I claim that these bifurcations are the natural explanatory construct for the dramatic patterns of change observed in historical linguistics. Third, I investigate the role of natural selection, communicative efficiency, and learning in the origin and evolution of language. In particular, I investigate the conditions under which shared languages (communicative systems) might emerge. I show that if individuals learn from a single agent in the population, then natural selection is necessary for the emergence of shared languages. On the other hand, if individuals learn from multiple agents in the community (social learning), then shared languages might emerge even in the absence of natural selection.

It is natural to compare linguistic and biological evolution. In biological evolution, one studies how biological (genotypic or phenotypic) diversity evolves under the action of various inheritance mechanisms (sexual and asexual reproduction) and natural selection. In language evolution, one studies how linguistic (syntactic, phonological, and so on) diversity evolves. However, the mechanism of transmission is not inheritance. Rather, it is learning by individual children. Moreover, whereas in biological evolution, one acquires (via inheritance) one’s genes from one’s parents alone, in linguistic evolution, one might acquire linguistic features from a greater variety of individuals. Further, the sense in which natural selection and fitness may be meaningfully considered in language evolution remains unclear. These similarities and differences have marked the history of both subjects. Since the promulgation of the Indo-European thesis by William Jones, historical linguistics was the preoccupation of linguists of the nineteenth century. Darwin was clearly influenced by some of these ideas and in the Descent of Man, he has often remarked on these analogies. In the twentieth century, evolutionary ideas were integrated with the genetic and molecular biology revolution. Correspondingly, the traditional questions of nineteenth century linguistics are being reformulated with the insights of modern generative linguistics.

The study of language evolution has a special significance in the scheme of things because it makes it possible for us to transmit information in a non-genetic manner across generations. That is why, as humans, we have such a profound sense of history, culture, and tradition. Learning, rather than inheritance, is the basis of this transmission of information. It is of interest, therefore, to understand the evolutionary properties of systems where the mechanism of transmission is learning rather than inheritance. More
generally, my effort to understand the relationship between the population and the individual is a variation on a theme that cuts across many subjects where one studies the behavior of a complex system of many interacting components. Statistical physics, population biology, individual and collective choice in economics, and the study of social and cultural norms provide other examples.

This book represents a small step toward a larger understanding of the issues in language learning and evolution. This larger understanding will require mathematical models, computer simulations, empirical data analysis, and controlled experiments. The insights will illuminate the nature of communication in humans, animals, and machines. They will have implications for how information is acquired and propagated in linguistics, biology, and computer science.

P.N.

*Chicago*

*December 2005.*