In this chapter, we consider the problem of language change. Linguists have to explain not only how languages are learned (a problem we investigated in the previous chapter), but also how and why they have evolved in certain trajectories. While the language learning problem has concentrated on the behavior of the individual child, and how it acquires a particular grammar (from a class of grammars $\mathcal{G}$), we consider, in this chapter, a population of such child learners, and investigate the emergent, global, population characteristics of the linguistic community over several generations. We argue that language change is the logical consequence of specific assumptions about grammatical theories, and learning paradigms. In particular, we are able to transform the parameterized theories, and memoryless algorithms of the previous chapter into grammatical dynamical systems, whose evolution depicts the evolving linguistic composition of the population. We investigate the linguistic, and computational consequences of this fact. From a more programmatic perspective, we lay a possible logical framework for the scientific study of historical linguistics, and introduce thereby, a formal diachronic criterion for adequacy of linguistic theories.

5.1 INTRODUCTION

As is well known, languages change over time. Language scientists have long been occupied with describing language changes in phonology, syntax, and semantics. There have been many descriptive and a few explanatory accounts of language change, including some explicit computational models. Many authors appeal naturally to the analogy between language change and another familiar model of change, namely, biological evolution. There is also a notion that
language systems are adaptive (dynamical) ones. For instance, Lightfoot (1991, chapter 7, pages 163–65ff.) talks about language change in this way:

Some general properties of language change are shared by other dynamic systems in the natural world...

Indeed, entire books have been devoted to the description of language change using the terminology of population biology: genetic drift, clines, etc. However, these analogies have rarely been pursued beyond casual and descriptive accounts.¹ In this chapter we would like to formalize these linguists' intuitive notions in a specific way as a concrete computational model, and investigate the consequences of this formalization. In particular, we show that a model of language change emerges as a logical consequence of language learnability, a point made by Lightfoot (1991). We shall see that Lightfoot's intuition that languages could behave just as though they were dynamical systems is essentially correct, and we can provide concrete examples of both "gradual" and "sudden" syntactic changes occurring over time periods of many generations to just a single generation.²

Not surprisingly, many other interesting points emerge from the formalization, some programmatic in nature:

- We provide a general procedure for deriving a dynamical systems model from grammatical theories and learning paradigms.

- Learnability is a well-known criterion for testing the adequacy of grammatical theories. With our new model, we can now give an evolutionary criterion. By this we mean that by comparing the evolutionary trajectories of derived dynamical linguistic systems to historically observed trajectories, one can determine the adequacy of linguistic theories or learning algorithms.

- We explicitly derive dynamical systems corresponding to parameterized linguistic theories (e.g. Head First/Final parameter in HPSG or GB grammars) and memoryless language learning algorithms (e.g. gradient ascent in parameter space).

- Concretely, we illustrate the use of dynamical systems as a research tool by considering the loss of Verb Second position in Old French as compared to Modern French. We demonstrate that, when mathematically modeled by our system, one grammatical parameterization in the literature does not seem to permit this historical change, while another does. We are also able to more accurately model the time course of language change. In particular, in contrast to Kroch (1989) and others, who mimic population biology models by imposing an S-shaped logistic change by assumption, we show that the time course of language change need not be S-shaped. Rather,

¹Some notable exceptions are Kroch (1990), Clark and Roberts (1993).
²Lightfoot 1991 refers to these sudden changes, acting over 1 generation, as "catastrophic" but in fact this term usually has a different sense in the dynamical systems literature.