Preface to "The Emergence of Language"

Brian MacWhinney

If you spend time watching the checkout lines at a supermarket, you will find that the number of people queued up in each line stays roughly the same. There are rarely six people in one line and two in the next. There is no socially articulated rule governing this pattern. Instead, the uniformity of this simple social "structure" emerges from other basic facts about the goals and behavior of shoppers and supermarket managers.

Honeybees are certainly no smarter than shoppers. However, working together, bees are able to construct an even more complex structure. When a bee returns to the hive after collecting pollen, she deposits a drop of wax-coated honey. Each of these honey balls is round with approximately the same size. As these balls get packed together, they take on the familiar hexagonal shape that we see in the honeycomb. There is no gene in the bee that codes for hexagonality in the honeycomb, nor is there any overt communication regarding the shaping of the cells of the honeycomb. Rather, this form is an emergent consequence of the application of packing rules to a collection of honey balls of roughly the same size.

Nature abounds with examples of emergence. The outlines of beaches emerge from interactions between geology and ocean currents. The shapes of crystals emerge from the ways in which atoms can pack into sheets. Weather patterns like the Jet Stream or El Niño emerge from interactions between the rotation of the earth, solar radiation, and the shapes of the ocean bodies. Biological patterns emerge in very similar ways. For example, the shapes of the stripes on a tiger are controlled by the timing of the expression of a pair of competing genes expressing color as they operate across the developing tiger embryo. No single gene directly controls these patterns. Rather, the stripes emerge from the interactions of the genes on the physical surface of the embryo. The shape of the brain is very much the same. For example, Miller, Keller, and Stryker have shown that the ocular dominance columns described by Hubel and Weisel in their Nobel-prize-winning work may emerge as a solution to a competition between projections from the different optic areas during synaptogenesis in striate cortex.

Emergentist accounts of brain development provide useful ways of understanding the forces that lead to neuronal plasticity, as well as neuronal commitment. The chapters in the current volume take off from this basic theme and elaborate a vision of emergentism that extends to a wide variety of topics in language processing, structure, and acquisition. Sticking close to this biological grounding, Elman's chapter in this volume summarizes work showing how the wiring pattern of the brain emerges from the interaction of a variety of developmental pressures. For example, Ramachandran has shown that many aspects of reorganization depend upon the elimination of redundant connectivity patterns. Moreover, Quartz and Sejnowski have shown that plasticity may also involve the growth of new patterns of connectivity. On the macro level, recent fMRI work by MacWhinney, Booth, Feldman, and Thulborn has shown how children with early brain lesions use a variety of alternative developmental pathways to preserve language functioning.

Students are often taught that the opposition between nativism and empiricism is the fundamental issue in developmental psychology. However, what they really end up learning is that everything in human development ends up depending on the interaction between nature and nurture. Unfortunately, students are given few conceptual tools to understand how this interaction occurs. As a result, they end up being confused about the underpinnings of the science of human development. Emergentism replaces the traditional opposition between nativism and empiricism with a new conceptual framework, explicitly designed to account in mechanistic terms for interactions between biological and environmental processes. The goal of emergentism is the construction of models that avoid stipulation regarding specific hard-wired neural circuitry. In the place of stipulation, emergentism provides accounts in which structures emerge from the interaction of known processes.

This strong formulation of the emergentist program must be tempered with practical reality. The primitive state of our understanding of basic neurological and developmental processes means that models often still have to rely on stipulation regarding structures that we do not yet fully understand. For example, a model of the effects of auditory processing deficits may need to include a hand-wired representation of information passed on to language processing from the auditory cortex. This type of stipulation regarding structures that are not at the core of a given model reflects the primitive nature

of our current modeling techniques. It is not intended as a statement about how models should be constructed.

Emergentism should not be interpreted as a radical rejection of either nativism or empiricism. On the contrary, emergentism views nativist and empiricist formulations as partial components of a more complete account. The traditional contrast between nativism and empiricism revolves around the fact that they describe developmental processes that operate across different time frames. We can distinguish five separate time frames.

1. **Evolutionary emergence**. The slowest moving emergent structures are those which are encoded in the genes. These structures, which are subject to more variability and competition than is frequently acknowledged, are the result of glacial changes resulting from the pressures of evolutionary biology. We can refer to this type of emergence as "evolutionary emergence".
2. **Embryological emergence**. Translation of the DNA in the embryo triggers a further set of processes from which the initial shape of the organism emerges. Some structures are tightly specified by particular genetic loci. For example, the recessive gene for phenylketonuria or PKU begins its expression prenatally by blocking the production of the enzymes that metabolize the amino acid phenylalanine. Although the effects of PKU occur postnatally, the determination of this metabolic defect emerges prenatally. Other prenatal emergent structures involve a role for physical forces in the developing embryo. The formation of the stripes of the tiger is an example of this type.
3. **Developmental emergence**. The emergentist accounts presented in the current volume focus primarily on the ways in which linguistic and cognitive structures emerge during learning and development. Jean Piaget's genetic psychology was the first fully articulated view of this type. Current emergentist accounts rely on perspectives such as connectionism, embodiment, and dynamic systems theory. Chapters in this book by Bates and Goodman, Elman, Goldberg, Smith, Stemberger, and Merriman explore these aspects of language emergence.
4. **On-line emergence**. The briefest time frame for the study of emergent processes is that of on-line language processing. Chapters by Aslin, Saffran, and Newport,

Dell and Gupta, Miikkulainen, MacWhinney, Allen and Seidenberg, and MacDonald investigate the ways in which language structure emerges from the activities of speaking and listening.

5. **Diachronic emergence**. The changes that languages undergo across centuries can also be viewed in emergentist terms. The chapters by Givón and MacWhinney explore some aspects of this type of emergence.

In order to qualify as emergentist, an account of language functioning must tell us where a language behavior "comes from". In most cases, this involves accounting for a behavior in a target domain as emerging from some related external domain. For example, an account that shows how phonological structures emerge from physiological constraints on the vocal tract involves external determination, since the shape of one level of description is determined by patterns on a different level.

No full account of language emergence has yet been developed. However, emergentist accounts have been formulated for a wide variety of linguistic phenomena, ranging from segmental inventories, stress patterns, phonotactic constraints, morphophonological alternations, lexical structures, pidginization, second language learning, historical change, on-line phrase attachment, and rhetorical structures. Formalisms that have been used to analyze the emergent nature of these forms include connectionist networks, dynamic systems theory, neuronal competition models, classifier systems, production-system architectures, Bayesian models, Optimality Theory, principles-and-parameters theory, corpora studies, and hermeneutic analysis. It is remarkable that approaches as apparently divergent as functionalist linguistics and principles-and-parameters theory share some common ground in terms of a mutual interest in emergentist accounts of both learning and processing.

The 16 papers presented here were delivered between May 29 and 31, 1997, at the 28th Carnegie Mellon Symposium on Cognition with the theme "Emergentist Approaches to Language Acquisition" and sponsored by the National Science Foundation. Apart from the invited speakers, nearly a hundred additional researchers attended the symposium.

Many of the 16 papers presented at this symposium adopt an explicitly emergentist approach. Elman examines basic issues in emergentist theory through the consideration

of gene-gene interactions, neuronal plasticity, and the ways in which temporal interactions in neural structures can lead to emergent computational abilities. The background for the themes that Elman develops here is discussed in greater detail in the book entitled "Rethinking Innateness" that was recently published by Elman and his colleagues. In many ways the themes developed in the current symposium volume can be viewed as follow-ups to the issues raised in that book.

Two other chapters explore the ways in which grammar emerges from the lexicon. Using the Construction Grammar framework, Goldberg traces the emergence of the semantics of argument structure during language acquisition. Bates and Goodman apply a similar perspective to the understanding of individual differences in early language development. In both articles, the authors view syntactic form as emerging from lexical learning. Goldberg grounds her account on linguistic analysis and recent experimental findings. Bates and Goodman rely more on the examination of correlations between lexicon and grammar across the first two years of language acquisition. Looking at a wide variety of special populations, including Down syndrome children, late talkers, precocious talkers, children with brain lesions, and Williams syndrome children, Bates and Goodman find little support for the nativist notion of a separate module for grammar.

The next two chapters look at adult sentence processing using the tools of connectionist modeling. Allen and Seidenberg study the ways in which judgments regarding degrees of grammaticality can emerge from competitive processing in connectionist networks. Their findings call into question the status of Chomsky's competence-performance distinction by showing how "competence" emerges from "performance". Miikkulainen and Mayberry study ambiguity effects in sentence processing effects that have often been used to argue for a modular basis for sentence processing. They present an explicit connectionist model in which the process of settling on a particular interpretation for an ambiguous sequence emerges on-line from the interaction of a set of "soft" semantic, lexical, and syntactic constraints.

Three other chapters examine the emergence of the shape of grammar from language usage. Looking at data on competitive syntactic attachments, MacDonald argues that the incremental shape of sentence processing emerges from distributional forces in the language. However, she also notes that a full understanding of the role of these

distributional pressures requires an understanding of the relations between comprehension, production, and acquisition. Like MacDonald, MacWhinney sees the form of comprehension, production, and acquisition as emerging from underlying cognitive pressures. MacWhinney presents a view of syntactic form as emergent from a process of perspective-taking in which both listener and speaker develop an embodied representation of the meaning of a sentence. He attempts to link linguistic form to the activity of perspective-taking across four cognitive levels, including affordances, spatial frames, causal action frames, and social frames.

Givón takes a slightly different approach to the way in which grammar formalizes cognitive operations. He argues that functional pressures have their greatest impact on incompletely consolidated forms of human language such as child language, pidgins, second language forms, and aphasic language. On the other hand, according to Givón, the full adult grammar of a language achieves a level of automaticity that escapes this type of direct functional pressure. Givón's analysis, like MacDonald's suggests that we must reject simplistic attempts to account for all aspects of language form as emerging from any single source such as conversational pressure, distributional patterns, perspective-taking, or working memory load. Rather, we may need to view grammar as a rarified response to the complete configuration of this entire set of dynamics.

Seven other papers deal explicitly with language acquisition. In the lone paper that explores specifically social influences, Snow challenges the relevance of accounts that attempt to view syntactic and semantic bootstrapping as the motors driving language learning. She suggests that we should take a close look at what children are good at, rather than those abilities they do not yet master. In particular, Snow believes that children have a precocious understanding of social relations and that their most advanced uses of language are grounded on this understanding. Like Bates and Goodman or Goldberg, Snow believes that grammatical advances are very much linked to lexical advances, and she adds to this perspective an emphasis on the role of parental input in fostering language development.

Three papers examine emergentist mechanisms for early word learning. Smith argues for the idea that "general learning processes make specialized learning mechanisms." In a series of experiments, she shows how the child learns to learn new words. At first the

child's guesses about the meanings of new words are relatively unfocused. However, as children learn more about language, these biases sharpen. Smith documents the emergence of these abilities in terms of both the shape bias for word learning and the ways in which the child uses linguistic frames to guess at the part of speech of a new word. Merriman articulates a point of view that is highly compatible with Smith's. He believes that children's word learning is governed primarily by the two basic forces of competition and attention. Attentional processes help the child focus in on possible candidate meanings for new words. Once these initial candidates emerge, they engage in a process of competition to control overgeneralizations. According to Merriman, the basic shapes of early words are determined not by innate constraints, such as Mutual Exclusivity, but by emergent processes. Golinkoff, Hirsh-Pasek, and Holllich present a slightly different approach to similar phenomena. They emphasize the extent to which an adequate account of early word learning must be based not only on cognitive principles, but also on social forces. Presumably, they have in mind the same types of social pressures emphasized by Snow, as well as the attentional focusing processes discussed by Merriman and Smith. Together, these articles paint a picture of early word learning in which the emergence of particular meanings is governed by a rich interaction between cognitive and social forces.

In the first year of life, before they approach the learning of the first words, children are exposed to a massive amount of auditory linguistic input. Until recently, our understanding of the child's processing of this input has focused on the acquisition of phonemic contrasts. Aslin, Saffran, and Newport present data on a new line of research with infants that goes well beyond this earlier literature. These new studies have shown us that eight-month-old children can group sequential auditory patterns solely on the basis of their distributional properties. They can use this ability to acquire the auditory forms of potential new words, as well as the intonational patterns of the language. Aslin et al. are careful to assume an agnostic approach to the interpretation of these findings as supporting an emergentist view, pointing out that the ability itself may be a part of an innate language acquisition device. However, they seem to recognize the fact that the child can use this ability as a powerful tool for language acquisition. Although this

ability itself may not be treated as emergent, the action of the ability on input leads to emergent structures.

Plaut and Kello adopt a more specifically emergentist approach to phonological learning in a model that attempts to link up the child's learning of input, auditory forms to early articulatory productions. Using an innovative connectionist architecture, they show how many of the properties of early child articulations emerge from the way in which data is processed by these networks. This emergentist view of output phonology is very much in accord with Stemberger and Bernhardt's application of optimality theory to the study of child language. The theory of optimality provides a powerful constraint satisfaction formalism for describing certain types of emergent patterns, particularly in the area of phonology. Stemberger and Bernhardt view children's early articulations as strongly influenced by reduction of adult target forms. In order to move their pronunciations closer to the adult target, children must improve the ways in which they maintain "faithfulness" to the target. This application of optimality theory is important not only for its theoretical clarity, but also for its exploration of the roots of the constraints envisioned by optimality theory. In particular, Stemberger and Bernhardt see these constraints as emerging from both phonetic and cognitive processes.

Phonetic processes, involving the movements of articulators such as the tongue and larnyx are surely the sources of many phonological constraints. However, higher level lexical processes must also have a major impact. Gupta and Dell explore two possible ways in which phonological form emerges from lexical structure. First, they note that the serial organization of words into chains gives rise to a basic asymmetry between the beginnings of words and their ends. For example, a phrase like "smell bad" may have onsets exchanged, as in "bell smad" or rimes exchanges, as in "smad bell", but final consonants are seldom exchanged, as in "smed bal". Using a conectionist model, Gupta and Dell show that a good vocabulary is one in which words tend to be more differentiated at the beginning than at the end. Looking still more deeply into processing influences on the lexicon, Dell and Gupta show how many aspects of word learning can be viewed as emergent from basic facts about procedural learning and its neuronal implementation.

These papers constitute a unique outpouring of creative energy. At the same time they personify an important new direction in thinking about language structure and language learning. By eschewing the simplistic application of nativism and empiricism, these researchers have opened up rich new areas for theory and research. It would be a mistake to think that all of these papers subscribe to some uniform emergentist "party line." For example, Aslin et al. explicitly declare their interest in pursuing nativist accounts for sequential learning. Aspects of the optimality theory formalism adopted by Stemberger and Bernhardt involve the provisional acceptance of a non-emergent level of formal representation. MacWhinney's views on perspective-taking make frequent reference to inborn processes and affordances. Finally, Givón emphasizes the extent to which grammar is non-functional, automatic, and non-emergent, at least in terms of what I have called on-line emergence, although Givón is willing to accept an important role for diachronic emergence.

This volume fails to include work from several related points of view. First, work on the emergence of grammar from conversation of the type presented by Hopper, Chafe, or Thompson is not represented. Second, recent work by Feldman, Lakoff, Narayanan, and associates on the linkage of language to fully embodied representations is missing, as is work on emergent properties in robotic and artificual life systems. Third, there is a lamentable absence of contributions from researchers in the tradition of generative grammar. Recent developments within the theory of generative grammar, as well as psycholinguistic extensions of the generative framework, have suggested that linguistic theory may eventually be compatible with an emergentist framework. However, these connections remain to be explored. Fourth, this volume includes no representative of the fascinating new work that is currently appearing on the emergence of language during evolution of man from the primates. Finally, this volume has explicitly excluded studies grounded on cognitive neuroscience, since this would have taken us well beyond the scope of this conference. There is an enormous amount of work in cognitive neuroscience that strongly motivates an emergentist approach. Whether it be work on adult neuronal plasticity, the organization of neural nets, or the development of the brain in the fetus and infant, each year sees new breakthroughs in our understanding of the biological bases of emergent processes. Fortunately, this omission is being addressed as

this book goes to press. Just as the 28th Carnegie Symposium on Cognition focused on the emergence of language, the 29th symposium, that was held in October 1998 focused on the biological underpinnings of emergence.

Emergentism provides a conceptually solid way of linking our growing understanding of the brain with new theories of cognition, as well as new tools for simulation. By distinguishing levels of emergence across the five time scales mentioned above, we can incorporate the old opposition between nativism and empiricism into a detailed new research proogram. By linking these tools together in a single framework, we open up the promise that the next millenium will begin with a productive outpouring of new ways of thinking about the emergence of language.