nodes, there are 2^n linear orders. This can quickly lead to large numbers, but these are still smaller than the $m(!)$ possible permutations that would result from m constituents (for $m = 3$ as in the present example, this gives six).

The present proposal is that syntax does indeed provide only for the more modest constraints given by a-temporal syntax. A-temporal syntax is sufficient to specify a crucial ingredient of syntax, called structure-dependence in many of Chomsky's publications. Structure dependence is decidedly not the specification of linear order, but the specification of domination and sisterhood alone.

Order of constituents is only partially determined by structure dependence. The remaining task is that of phonology, semantics, and pragmatics combined. I have nothing to say about the latter two, but will assume that principles of information structure (such as "Agent First" and "Focus Last," *Foundations,* Ch. 8, sect. 8.7) are of primary importance here. Again, avoidance of duplication seems to make a syntactic determination of order superfluous at best in those cases in which other principles are at work already.

4. The role of phonology. As for linear order in phonology, it is indisputable that phonology (in contrast to syntax) needs linear order as a core concept. The string of phonemes /pit/ is in contrast with the string /tip/, while /ipt/ is a possible, but unrealized word in English, and any other permutation of the three phonemes is ill-formed in English. In other words, the elementary notions of contrast, distinctiveness, and well-formedness in phonology include linear order. Structuralist phonology used the term "syntagmatic relation" in this connection; here, "syntagmatic" literally means "in accordance to the time axis." Furthermore, a number of phonological rules are generally cast in terms of linear order. For example, the basic rule of compound stress in English or German says that the *first* of two parts in a compound carries main stress. For stress in phrases, the reverse holds (simplifying considerably): the *second* of two constituents in a phrase receives main stress. In other words, phonology is very much about the temporal line-up of chunks of speech. Given that it is grounded in the phonetics of speech, this does not come as a surprise.

Furthermore, some of the syntactic movement operations assumed in syntactic theory are clearly related, at least functionally, to either information structure (as in "topic first") or to preferred positions for constituents with either strong stress (focus positions) or weak stress (deaccentuation). Given that syntax is not conceived as "knowing" about nonsyntactic principles such as stress, it is almost inevitable to assign the respective movement operations to some other domain.

5. Where does order come from? If the present hypothesis about temporally unordered syntactic constituents should be correct, it would leave us with one crucial question: From what rules or principles does the actual order (encoded in phonological structures) derive? No complete answer can possibly be given here, but parts of the answer have been identified already: Jackendoff points out in several places that there are principles of ordering which are part of semantics, information structure in particular, and of phonology, heaviness constraints and stress preferences in particular.

Lexical information (either on individual items or on more or less extended lexical classes) must be another source of temporal order: Prepositions versus postpositions are an obvious example, prenominal versus postnominal adjectives might provide a further case.

Next, phonology itself provides ordering information, as we can see from principles, such as the one requiring long constituents to follow short ones (Behaghel's law).

Setting aside the cases just enumerated, there are substantial remaining problems. My formal proposal at this point is that the rules providing the interface between syntax and phonology – Jackendoff's "PS-SS interface rules" (Ch. 5, sect. 5.6) – provide the natural locus for stating the constraints on linear order for syntactic and/or semantic constituents. Such rules are, by necessity, sensitive to information stemming from both of the components between which they mediate. Here again, the architecture of grammar proposed by Jackendoff provides a fruitful base for further research.

How did we get from there to here in the evolution of language?

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Abstract: Jackendoff's scenario of the evolution of language is a major contribution towards a more rigorous theory of the origins of language, because it is theoretically constrained by a testable theory of modern language. However, the theoretical constraints from evolutionary theory are not really recognized in his work. We hope that Jackendoff's lead will be followed by intensive cooperation between linguistic theorists and evolutionary modellers.

There has been a vigorous debate in the evolution of language literature on whether the human capacity for language evolved gradually or with an abrupt "big bang." One of the arguments in favor of the latter position has been that human language is an all or nothing phenomenon that is of no value when only part of its apparatus is in place. From a developmental perspective this has always been a peculiar argument, seemingly at odds with the gradual development of phonological, syntactic, and semantic skills of infants. In the context of the evolution of language, the argument was eloquently refuted in a seminal paper by Pinker and Bloom (1990). However, Pinker and Bloom did not go much further than stating that a gradual evolution of Universal Grammar was possible. They did not explore the consequences of such a view for linguistic theory, and their approach was criticized by both the orthodox generativists and the latter's long-term opponents.

Jackendoff (2002) has now gone one step further. If linguistic theory is incompatible with gradual evolution and development, perhaps linguistic theory needs to be revised. Jackendoff has written a powerful book around the thesis that the language capacity is a collection of skills ("a toolbox"). Some of these skills are language-specific, some not, and each of them is functional even without all or some of the other skills present. From his decomposition of linguistic skills follow a number of hypotheses on plausible intermediate stages in the evolution of language, that fit in neatly with many other theories, models, and findings in this field.

Jackendoff's book therefore presents a significant departure from the generative, "formalist" tradition, where the evolution of language has received little attention. In this tradition, the structure of human language has often been viewed as accidental rather than as adapted to the functions that language fulfills in life. Chomsky and others have been dismissive about attempts to reconstruct the evolution of language, which they regard as unscientific speculation. Chomsky famously observed that "we know very little about what happens when 10^{10} neurons are crammed into something the size of a basketball" (Chomsky 1975).

In contrast, Jackendoff presents the different tools from the "toolbox" as adaptations for better communication. Moreover, he gives a rather complete scenario of successive, incremental adaptations that is consistent with his view on how modern language works, and how it can be decomposed. Interestingly, he argues that present-day languages show "fossils" of each of the earlier stages: expressions and constructions that do not exploit the full combinatorial apparatus of modern language. Jackendoff's book is therefore a major contribution towards a more rigorous, scientific theory of the evolution of language, in part because it leads to some testable predictions, but more importantly because it is theoretically constrained by a testable theory of modern language.

However, Jackendoff does not really recognize that, in addition, evolutionary theory brings stringent theoretical constraints (Barton & Partridge 2000). Good evolutionary explanations specify the assumptions on genotypic and phenotypic variation and selection pressures, of which the consequences can be worked out in mathematical and computational models. For instance, Nowak et al. (2001) derive a "coherence threshold" for the evolution of language, which poses a strict constraint on the accuracy of both genetic and cultural transmission of language for linguistic coherence in a population to be possible. In this type of work, one often finds that "adaptive explanations" that seem so obvious in a verbal treatment such as Jackendoff's, are in fact insufficient.

Cavalli-Sforza and Feldman (1983) studied a "conformism constraint" that arises from the positive frequency dependency of language evolution: Linguistic innovations are not advantageous in a population where that innovation is very infrequent. Imagine, for instance, a population that is in the second state of Jackendoff's scenario. That is, individuals can use a large vocabulary of learned signals in a non-situation-specific manner, but their language is not compositional: Signals cannot be analyzed as consisting of meaningful parts. Suppose that a child is born with a genetic mutation that makes her more inclined to analyze sentences compositionally. Would this child profit significantly from this mutation, even if the language of the population she is born into is not at all compositional? If not – and it takes some creativity to come up with reasons why she would – evolutionary theory predicts that the new gene will disappear through negative selection or random drift (Fisher 1922).

That is not to say that language did not evolve according to Jackendoff's scenario, but just to emphasize that each of the transitions between the phases he proposes is a challenge in itself. The evolution of language is not, as is sometimes suggested, a domain for just-so stories. Rather, it turns out that it is very difficult to find even a single plausible scenario for the evolutionary path from primate-like communication to the sophisticated toolbox of human language that will survive close scrutiny from mathematical and computational modeling. Recently, this insight has led to a surge in the interest in "explorative," computational models (see Kirby 2002b; Steels 1997; for reviews). They have yielded intriguing ideas on adaptive and nonadaptive explanations for the emergence of shared, symbolic vocabularies (e.g., Oliphant & Batali 1996), combinatorial phonology (e.g., de Boer 2000; Oudeyer 2002), compositionality and recursive phrase-structure (e.g., Batali 2002; Kirby 2002a).

For instance, the suggestion of Kirby (2000) – referred to but not discussed in Jackendoff's book – is that a process of cultural evolution might facilitate the emergence of compositionality. If a language is transmitted culturally from generation to generation, signals might frequently get lost through a bottleneck effect (that arises from the finite number of learning opportunities for the child). Signals that can be inferred from other signals in the language, because they follow some or other systematicity, have an inherent advantage over signals that compete for transmission through the bottleneck. With some sort of generalization mechanism in place (not necessarily adapted for language), one always expects a language to become more compositional (Kirby 2000), and, more generally, better adapted to the idiosyncrasies of the individual learning skills (Zuidema 2003).

Throughout his book, Jackendoff uses metaphors and terminology from computer science. Terms like processing, working memory, and interface make it sometimes appear as if he is describing a computer rather than processes in the human brain. However, nowhere do his descriptions become sufficiently formal and exact to make them really implementable as a computer program. In this light, his criticism of neural network models of language acquisition and his mentioning only in passing of computational models of the evolution of language is unsatisfactory. Jackendoff's challenges for connectionists are interesting and to the point, but it is equally necessary for theories such as Jackendoff's, especially their implications for development and evolution, to be made more precise and to be extended in computational and mathematical models.

In sum, in the effort to find a plausible scenario for the evolution of human language, a book like Jackendoff's *Foundations of Language,* based on a broad and thorough review of linguistic theory and facts, is extremely welcome. But as explorative computational models such as the ones discussed have been very fruitful in showing new opportunities and constraints for evolutionary explanations of human language, we hope that Jackendoff's lead will be followed by intensive cooperation between linguistic theorists and evolutionary modellers.

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Author's Response

Toward better mutual understanding

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Abstract. The commentaries show the wide variety of incommensurable viewpoints on language that *Foundations of Language* attempts to integrate. In order to achieve a more comprehensive framework that preserves genuine insights coming from all sides, everyone will have to give a little.

R1. Goals

My goal in writing *Foundations of Language* was threefold. First, I wished to develop a framework for studying language – the parallel architecture – which would permit a better integration of all the subfields and theoretical frameworks of linguistics with each other and with the other cognitive neurosciences. Second, I wished to persuade linguists to join more fully in this integrative enterprise. Third, I wished to persuade cognitive neuroscientists outside linguistics that the past forty years have brought genuine insights in linguistic description – albeit somewhat obscured by the technical opacity of linguistic theory – and that the parallel architecture offers better prospects for renewed dialogue. The commentaries suggest that I have succeeded to some extent, but that there still is a long way to go and a lot of preconceptions to overcome (including, no doubt, my own). The difficulties of integration are legion: The study of language, more than any other cognitive capacity, stretches the limits of interdisciplinarity, all the way from neuroscience and genetics to social policy and literary theory, with linguistics, psychology, and anthropology in between.

Many of the commentators focus on issues in *Foundations* that are touched upon only tangentially or not at all in the précis appearing here. In this response I will do my best to make clear what is at stake. My hope, of course, is that readers will thereby be engaged enough to want to tackle the whole book.