

**Archontan relations.** Cladogram of archontan mammals, including the taxa discussed in the text.

its. Other plesiadapiforms have claws on all digits, whereas euprimates have nails on all digits (primitively). *Carpolestes* thus appears to exhibit an intermediate condition, providing the first evidence for the transition from claws to nails in primates.

The evolutionary history of grasping among archontan mammals is complex. The ancestral archontan or euar-chontan likely lived in trees (15, 17) and probably evolved a primitive form of grasping foot like that of *Ptilocercus* (11, 15, 16), with claws on all digits and without an opposable big toe. A more powerful, euprimate-like grasping foot with an opposable big toe, a nail on the big toe, and claws on the other digits then evolved in plesiadapiforms such as *Carpolestes*. Finally, orbital convergence and leaping evolved in euprimates.

As Cartmill explained, we “can only hope that new fossil finds will help us to tease apart the various strands of the primate story, giving us clearer insights into the evolutionary causes behind the origin of the primate order to which we belong” (12, p. 111). This is certainly true of the *Carpolestes* skeleton because we now have a much better idea of the sequence of

acquisitions in the primate lineage. Fortunately, the limestones of Wyoming should continue to produce fossils that will enlighten us about primate and mammalian evolution for years to come.

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#### PERSPECTIVES: LINGUISTICS

## Noam's Ark

Thomas Bever and Mario Montalbetti

Language is naturally viewed as a unique feature of being human. Accordingly, the study of what language is—linguistics—has been very influential, primarily in the social and behavioral sciences. On page 1569 of this issue, Hauser, Chomsky and Fitch (1) expand the scope of language study with their demonstration that complex behaviors in animals and non-linguistic behaviors in humans can inform our understanding of language evolution.

The origin of human language has been an evanescent topic in the history of ideas for many centuries. It pops up in philosophical debates as a conceptual exercise on the nature of humanity and then, just as capriciously, disappears from the intellectual scene. Two principal ideas have been presented in these forums that emphasize the functional basis of language or alternatively its expression of humanity. For example, Rousseau (2) famously argued that

language flows from emotions; shortly thereafter, Herder (3), a bit less famously, suggested that language is a special expression of human rationality. Of course, available theories of language and evolution vastly underdetermined empirical answers. In desperation, the 19th century Linguistic Society of Paris banned the inconclusive topic of the origin of language.

Darwin inaugurated a new era by creating an empirical basis for what had been a purely conceptual debate. He suggested that language emerges from more primitive emotional communication abilities in animals. The notion that language is a gradually selected capability timidly appeared, accompanied by new methods for studying morphological evolution that embraced comparative analyses of fossils and genetics. However, the best part of the 20th century contributed little to the subject because—as Hauser, Chomsky and Fitch point out—“linguistic behavior does not fossilize.” Understanding the relation between genetics and behavior is still in its infancy, and has been complicated by the absence of a clear model that delineates

what language itself is. Chomsky's linguistic theory—which redefined language as a cognitive computational faculty—afforded hope for a conceptually and empirically illuminating discussion of the evolution of language. In their review in this issue, Hauser *et al.* (1) sketch a broad programmatic outline of how to understand human language better by comparing its computational component to the computational capacities of our contemporary earthly coinhabitants, the ones that survived the flood.

A brief dip into recent linguistic history will help us to understand the importance of the authors' approach. Chomsky's first great impact on behavioral science was his notion that sentence structure can be studied independently of meaning. His notorious demonstration of this is the sentence “Colorless green ideas sleep furiously” (4). Although it is nonsense, it is nonetheless recognizable as a well-formed English sentence (compared, for example, with “Ideas green sleep furiously colorless”). The first step in the new linguistic science of sentence structure was to become more abstract, leaving behind meaning to study the pure laws of syntax.

This led to the formulation that even the simplest sentences have an inner “abstract” syntactic form. The problem for linguistic research became redefined: how the inner form is mapped onto the outer forms that

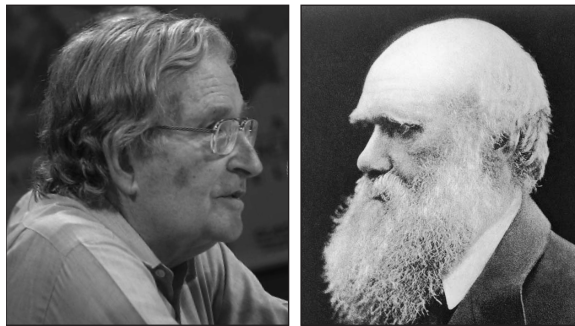
we hear and say. After 50 years of forming linguistic theories, Chomsky (5–7) now suggests that the essential mapping process can be reduced to two basic operations: *merge* and *displacement*. The first combines (lexical) units in a hierarchical structure, resulting in phrase structure trees that are relatively familiar; the second displaces a unit previously merged by merging it again at a different location in the structure and leaving a copy of it behind. This is illustrated by English sentences like “Mary, John likes [mary]” and “Who does John like [who].” Even though “Mary” and “Who” appear at the beginning of their respective sentences, they must be interpreted in their original merge positions (that is, after “likes” and “like,” respectively).

The idea that an unconscious level of representation could be mapped at a conscious level set the field of language study (at that time largely populated by behavioral biologists, operationalists, and nominalists) on its ear. Next, the field of psycholinguistics sought to establish the psychological basis for Chomsky’s postulates of innate language structure and transformational grammar. This was accompanied by developments in allied “hybrid” disciplines such as neurolinguistics. (Neurolinguistics specifies the neurological mechanisms underlying different components of linguistic theory, and has moved from primary dependence on aphasic research to modern brain-imaging techniques). Thus, linguistics research now centers on the capacities developed during childhood that could account for the richness and diversity of adult language, especially given the impoverished linguistic environments in which children are often nurtured. The complexity of what is acquired functionally and represented neurologically underlies the sometimes controversial claim that language is “innate,” a claim that will be enriched by Hauser *et al.*’s evolutionary perspective.

Two developments since Chomsky’s initial formulations of syntactic theory provide the theoretical underpinnings for Hauser *et al.*’s programmatic study of language evolution. The focus has shifted from describing factors manifest in external language (E-language) to describing abstract internal language universals (I-language) (8). Hauser and colleagues argue that what is at issue is not how language evolved to communicate or represent ideas, but rather how the central core of I-language computations can be delineated. They access the recent idea that I-language is essentially a “minimal” mapping between form and meaning, and can ultimately be reduced to an optimal set of processes. Thus, the study of syntax be-

comes the study of the immediate perfect “engine” driving syntactic computations—what the authors term “faculty of language in a narrow sense” (FLN). Other contributing biological features of language are relegated to the “faculty of language in the broad sense” (FLB).

So, what is at the center of this perfect engine of syntax? Hauser *et al.* crystallize a long-held intuition—that the essential process of syntax is recursion, the ability to generate an infinite array of expressions from a limited set of elements. Recursion appears in a wide range of human behaviors. For example, a childhood pastime defines the concept of “it” in a game of tag, namely, “the kid who was tagged by the kid” (who was tagged by the kid...who was originally



**The descent of language.** Noam Chomsky (left) and Charles Darwin (right) differ in their view of the part played by emotion in the evolution of language.

“it”). And of course, recursion is an object of study in mathematics and logic. Hauser *et al.* suggest that recursion is also the central feature of the computational component of I-language. Accordingly, in addition to considering biological antecedents for FLB, the new broad field of “bio-comparative linguistics” explores the parallels and potential antecedents for recursion in other animals and other human behaviors.

A further question remains. If the components of FLB are shared with nonhuman species and the sole central component of FLN is shared with other human cognitive domains (and possibly other species), is there something particularly unique to human language? Chomsky has suggested that recursion itself is instantiated in human language by the two mechanisms of narrow syntax: *merge* and *displacement*. It is displacement that seems to have no parallel manifestation either in nonhuman animals or in other human cognitive domains. Thus, displacement might seem to be both unique to humans and unique to human language. But it is not totally unique to human theories of the mind. Jakobson, the giant of mid-20th century linguistics, noted that these two main linguistic mechanisms also underlie cognitive behavior and emotion (9). Hauser, Chomsky and Fitch

themselves tentatively point out that recursion may appear in other human activities, such as music, games, and social structures.

Chomsky’s theory is unparalleled among 20th century theories of behavior, with the single exception of Freud’s metapsychological investigations. These two models of the mind have striking parallels, if one considers the computational architecture that psychodynamic theory postulated for the emotional expression of internal emotional representations. Both Freud and Chomsky showed the utility of a stable and structured unconscious level of representation. They suggested two similar core mechanisms for mapping it onto more explicit representations: *association* (Freud’s “Verdichtung,” Chomsky’s “merge”) and *movement* (Freud’s “Verschiebung,” Chomsky’s “displacement”). For Freud (10), dream elements are symbols that are sometimes united with their underlying themes, and sometimes displaced from them. In fact, even what Hauser *et al.* claim is language’s innermost syntactic property (recursion) has a small manifest echo in Lacan’s metapsychological theory (11).

This brings us back to Rousseau and Herder: Perhaps we see now a glimmer of unification among the notions that human symbolic representations have both an emotional and a computational component.

What we may be working toward is a theory of the evolution of *human expression* in general. Whether this turns out to be a fruitful line of thought or not, Hauser *et al.* have taken the next step in presenting how we can empirically study the evolutionary basis of human language.

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