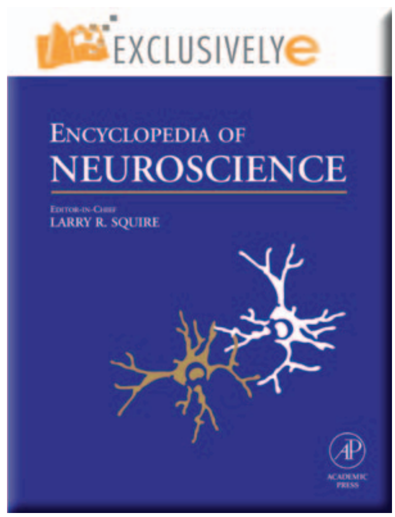

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Language Evolution

M H Christiansen, Cornell University, Ithaca, NY, USA; and Santa Fe Institute, Santa Fe, NM, USA
S Kirby, University of Edinburgh, Edinburgh, UK

Introduction

Language is often referred to as one of the hallmarks of our species. However, the emergence of language may be more than simply an important event in human evolution; it may be one of only eight 'major transitions' in the evolution of life, as listed by the two eminent evolutionary biologists John Maynard Smith and Eörs Szathmáry. Each major transition denotes a key event in the history of our planet, signaling radical changes in the way evolution works, starting with a change in the way molecules replicate in the very earliest stages of the origins of life, through the emergence of DNA, to larger scale subsequent phenomena such as the evolution of colonies where once there were only solitary individuals and including, as the most recent evolutionary transition, the emergence of language (Figure 1).

Why is the emergence of language such a significant event? What does it have in common with the other major evolutionary transitions? One of Maynard Smith and Szathmáry's interesting observations is that, despite their diversity, these transitions have some features in common. In particular, many of the transitions give rise to a new mechanism for the transmission of information. Language, they argue, provides just such a novel mechanism – essentially enabling a system of cultural transmission with unlimited heredity. As such, language enables the transmission and storage of very complex cultural information. But how did we, as human beings, evolve this powerful ability? Before discussing the possible answers to this question, we briefly survey the structural features of language that support this powerful information transmission system.

The Structure of Language

One way of thinking about language (although by no means the only way) is as a coding system that maps between two spaces: the space of concepts and intentions, on the one hand, and the space of articulation and perception, on the other hand (Figure 2). Traditionally, the study of the structure of language has been divided into a number of subdisciplines, each of which concerns a different aspect of this mapping system:

- *Phonetics*. The production and perception of sounds/manual gestures.
- *Phonology*. The systematic behavior of the sounds of language.
- *Morphosyntax*. The system for combining the basic meaningful units of language into words and sentences.
- *Semantics*. The meaning of words and sentences in isolation.
- *Pragmatics*. The system for relating word/sentence meaning to communicative intention in the context of communication.

The first and last two subdisciplines on this list deal mainly with the two ends of the mapping in Figure 2, whereas morphosyntax is most clearly the study of the aspects of language that govern how these two are connected, using words recruited from a mental lexicon.

What is extraordinary about this system, and what makes it particularly important for Maynard Smith and Szathmáry, is that it is constructed in such a way as to allow unbounded yet faithful transmission of information (sometimes termed 'digital infinity'). This combination of an infinite range of messages with a high-fidelity mechanism for transmitting those messages is almost unique in nature. Arguably, the only other example is the genetic code.

It is easy to understand why human language is in principle unbounded. If we were to try to find the longest sentence of English, we would fail. This is because the syntactic system delivers mechanisms that will allow us to elaborate on sentences in an unlimited fashion (e.g., by adding subordinate clauses, adverbial phrases, and prepositional phrases). This kind of infinity is 'digital' because it does not rely on continuous changes in the signal to convey changes in meaning but, rather, the addition of discrete elements. In contrast, we could imagine a different signaling system in which the pitch of a signal conveyed differences in meaning (e.g., the severity of a particular threat). This system would be infinite because there are infinitely many different pitches, but it would not be digital.

Another unusual aspect of human language is that the lexicon is flexible. New words can be added, and the meanings of words can change. Although this feature of language is not discussed as much as digital infinity, it is actually the combination of these two that really sets human language apart as a uniquely powerful tool for the unbounded transmission of cultural information. In summary, language structure allows high-fidelity, unbounded, and flexible communication.

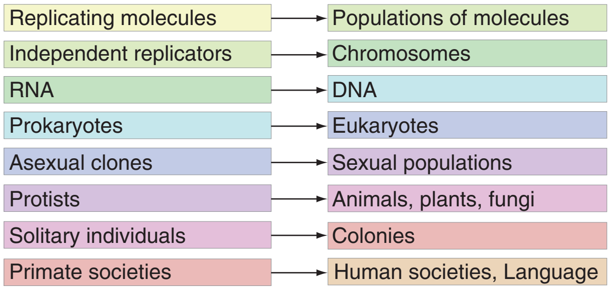

Figure 1 Maynard Smith and Szathmáry's eight major transitions in the evolution of life.

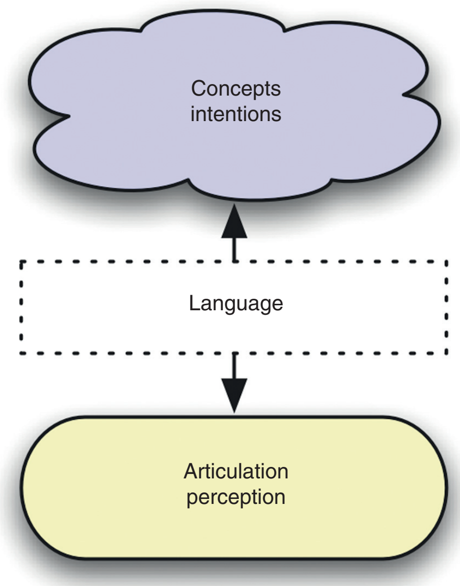

Figure 2 Language can be viewed as a system that maps between two different domains: concepts and intentions, on the one hand, and mechanisms for articulation and perception of speech (or gesture), on the other hand.

Questions surrounding the origins and evolution of language have, since the early 1990s, seen a major increase in interest in the scientific community, across a very wide range of disciplines. In the remainder of this article, we discuss major areas of consensus and current controversies. It is important to realize, however, that this is far from an exhaustive summary of a subject that draws on evidence from archeology to computer science, from genetics to philosophy.

Major Points of Consensus

Understanding language evolution poses many challenges for contemporary science, and the picture that is emerging is highly complex. Nonetheless, considerable progress has been made in the field of language evolution since it emerged as a legitimate area of scientific enquiry during the 1990s. Here, we first provide an overview of the major areas of consensus before discussing some of the current controversies.

Possible Preadaptations for Language

There is a general consensus that to understand language evolution, we need a good understanding of what language is. However, the field is divided over what the exact characterization of language should be, and in what terms it should be defined. Nonetheless, agreement appears to be in sight regarding some of the necessary steps toward language. Specifically, there seems to be agreement that prior to the emergence of language, some preadaptations occurred in the hominid lineage. There is less agreement about what these may have been, but one candidate that has been proposed by many is the ability to use symbols. In this context, symbol use is typically construed as a capacity for linking sounds or gestures arbitrarily to specific concepts and/or percepts – particularly for the purpose of communication. In addition, it has been suggested that the ability to relate these symbols to each other was a further necessary preadaptation for language. Although there is evidence that nonhuman primates have some capacity, albeit limited, for using sequences of arbitrary symbols in captivity, there is considerable debate regarding whether they use these symbols to refer things in nature. For example, the use of manual gestures for symbolic communication in the wild has been called into question. Thus, the use of complex sequences of symbols referring to objects and situations may be a uniquely human ability.

Several other possible candidates for language preadaptations have been put forward, of which we mention a few relating to changes in social or cognitive abilities. Joint attention – that is, the capacity to follow eye-gaze direction or direct the attention of another to a specific object – is important for successful communication, and it may have been a social precondition for language. Another potential social preadaptation for language is the capability of modern humans for sophisticated imitation of action sequences for the purpose of communication. Our ability to represent others as intentional beings with their own beliefs and desires, which can be manipulated by our actions, may also be a social prerequisite for language. At the cognitive level, an increase in the capacity for representing complex concepts and combinations thereof may have predated the emergence of language. Additional cognitive preadaptations that may have paved the way for language include the ability for complex hierarchical learning of sequentially presented information and increases in memory for sound sequences, both of which are important for learning and processing of language. It should be noted, however, that many of the preadaptations mentioned previously are shared with other species, particularly other primates, and that differences in these skills may be more quantitative in nature than qualitative.

The Necessity of Interdisciplinary Collaborations

Perhaps the strongest point of consensus among language evolution researchers is a methodological one: to fully understand language evolution, it must be approached simultaneously from many disciplines. We must understand how our brains work; how language is structured and what it is used for; how early language and modern language differ from each other and from other communication systems; in what ways the biology of hominids has changed; how we manage to acquire language during development; and how learning, culture, and evolution interact.

Thus, language evolution research must necessarily be cross-disciplinary in order to provide sufficient constraints on theorizing to make it a legitimate scientific enquiry. Nevertheless, most researchers in language evolution only cover parts of the relevant data, perhaps for the reason that it is nearly impossible to be a specialist in all the relevant fields. Still, as a whole, the field appears to be moving in the direction of becoming more interdisciplinary. Collaborations between researchers in different fields with a stake in language evolution are likely to become increasingly more important.

The Importance of Modeling

Another emergent area of consensus is the growing interest in using computational modeling to explore issues relevant for understanding the origin and evolution of language. Many researchers across a variety of different disciplines now either conduct language evolution simulations or refer to such work as evidence for particular theoretical perspectives. For example, modeling work has been used to inform high-level theories about biological adaptations for grammar or the emergence of language structure through cultural transmission but also at a more detailed level, such as the evolution of phonetic gesture systems or a neural basis for grasping as a precondition language based on manual gesture. Models are useful because they allow researchers to test particular theories about the mechanisms underlying the evolution of language. Given the number of different factors that may potentially influence language evolution, our intuitions about their complex interactions are often limited. It is exactly in these circumstances, when multiple processes have to be considered together, that modeling becomes a useful, and perhaps even necessary, tool.

The role of computational modeling in language evolution research can be divided into three rough categories.

1. Evaluation: Computational models, like mathematical models, have the virtue that they enforce explicitness in the formulation of an explanation. As such, they can act as a rigorous check that a particular explanandum actually does follow from a particular explanans. In other words, they can help researchers to identify hidden problems. In some sense, they allow us to create novel experiments to test under which conditions language evolves.
2. Exploration: Computational simulations can be used (with caution) to explore the general ways in which explanatory mechanisms or theoretical constructs interact. In this mode, simulations can help direct us to new theories.
3. Exemplification: Computational simulations can be a valuable tool for demonstrating how an explanation works. They can augment verbal and mathematical theorizing to provide working models for pedagogical purposes.

Computational modeling thus provides a powerful new tool for the study of language evolution. However, it cannot stand on its own. It must take its place alongside theoretical considerations, mathematical modeling, experimentation, and data collection (e.g., linguistic and archaeological). For example, some computational models may eventually lead to mathematical models, or vice versa. Computational models may suggest novel psychological experiments and so on. We envisage that the interest in computational modeling is likely to increase, especially as it becomes more sophisticated in terms of both psychological mechanisms and linguistic complexity.

The Usefulness of Comparative Approaches

An additional type of evidence that is becoming increasingly important is data from studies that directly compare the learning and processing abilities of nonhuman primates with those of humans (either adults or children) using the same experimental paradigms. For example, comparisons of 8-month-old human infants and cotton-top tamarins on a simple artificial language learning task using the same preferential head-turn methodology indicate that both species may have similar abilities for basic statistical learning. Such work may allow us to better determine which components of language may be unique to humans and which may be shared with other species. As a case in point, comparative evidence regarding sequential learning suggests that an important difference between human and nonhuman primates is our superior ability for learning and processing hierarchically organized temporal sequences. When combined with further corroborating evidence from neuropsychology and neurophysiology, computational simulations, and linguistic considerations, this human ability becomes a compelling candidate for a possible hominid biological adaptation that may eventually have led to the evolution of complex language. Future comparative research may reveal additional differences that can inform our understanding of language evolution.

Insights from Genetics

Advances in genetics are now figuring prominently in discussions of language evolution. As we obtain a better understanding of the genetic bases of language and cognition, as well as their interaction with the environment during development, genetic information promises to provide new constraints on language evolution theories, particularly with respect to issues related to the origin of language. However, the relationship between language and genes is extremely complex, and the relationship between genes, language, and evolution perhaps even more so. Consequently, current evidence provides few constraints on evolutionary theorizing. For example, data regarding the *FOXP2* gene have been cited in support for very different theories of language evolution, ranging from a gesture-based perspective to a speech-based perspective, from accounts involving large endowments of innate linguistic knowledge to accounts eschewing such innate knowledge. Nonetheless, there seems to be agreement that the FOXP2 data may suggest a late evolution of speech. In this way, the genetic data may be particularly useful in informing our understanding of the timeline for language evolution.

Current Controversies

Although much progress has been made and several areas of consensus have emerged, a number of major points of disagreement remain, of which we highlight the more current ones here.

Biological versus Cultural Evolution

Although there is considerable agreement about a possible symbolic preadaptation among our hominid ancestors prior to the emergence of language, opinions differ considerably about the subsequent evolution of grammatical structure.

One line of theorizing suggests that grammatical structure is a consequence of an evolved innate grammar. There are several different proposals regarding how and why a biological adaptation for grammar may have evolved in the hominid lineage by way of natural selection. One suggestion is that language evolved gradually as an innate specialization to code increasingly complex propositional information (e.g., who did what to whom, when, where, and why). This may have been for the purpose of social information gathering and exchange within a distinct 'cognitive niche' or for a kind of social 'grooming' at a distance in groups of hominids too large for establishing social cohesion through physical grooming. Another perspective suggests that grammar emerged more rapidly with the speciation event that produced modern humans approximately 120 000 years ago. Common to most of these proposals is the suggestion that language syntax shows evidence of complex design – similar to, for example, our visual system – and that biological adaptation is the only way to explain the appearance of such design.

A different line of theorizing views grammatical structure not as a product of biological adaptation but, rather, as emerging through cultural transmission of language across hundreds (or perhaps thousands) of generations of learners. Essentially, in this view language is an evolutionary system in its own right – but one driven by cultural rather than genetic evolution. This has interesting implications for Maynard Smith and Szathmáry's view of evolutionary transitions. They focus on language as a mechanism through which the transmission of cultural information is possible. The cultural approach to language evolution highlights the additional fact that knowledge of language itself is passed on culturally through the process of language learning by children.

Aspects of linguistic structure might therefore be viewed as adaptations by language to the cultural evolutionary 'problem' of being transmitted faithfully from generation to generation of language learners. In this approach, language is seen as adapting to the narrow transmission bottleneck imposed by children's learning mechanisms. Evidence in favor of this perspective has come from computer modeling of cultural transmission, the development of indigenous sign languages, and the archeological record of artifacts. Many proponents of this viewpoint on language evolution argue for a 'culture-first' perspective in which language evolved only after basic competences for relatively complex social culture had emerged in the hominid lineage. However, additional constraints would seem to be needed if the appearance of design in language is to be explained. Such constraints may be found in the limitations on our ability for sequential learning of hierarchical structure, in the learning bottleneck created by forcing languages through the limited channel of children's

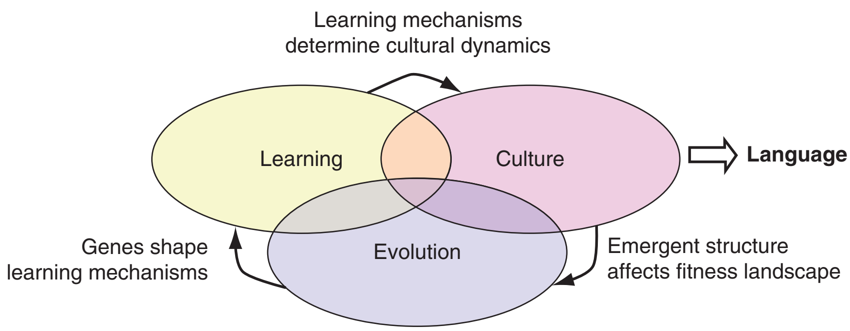

Figure 3 The complex adaptive systems view of language. Language arises from the interactions of three dynamical adaptive systems that operate on differing timescales: Biological evolution through natural selection shapes our mechanisms for learning language. Language emerges from the interaction of many individual learners through a process of cultural transmission and evolution. The structure of the language that emerges will partly determine the biological fitness of the possessors of that language, thus completing the cycle of interactions.

learning mechanisms, or in the complexities of our conceptual apparatus. Alone or in combination, these constraints have been suggested to explain the elements of language that give the appearance of design, such as linguistic universals.

It is likely, however, that biological adaptation and cultural transmission may have interacted in the evolution of language. Language arises from the interaction of three different adaptive systems: individual learning during development, cultural transmission across generations of learners, and biological evolution of the learners (Figure 3). Our understanding of such interaction is complicated by the fact that the three adaptive systems interact on three different timescales: the lifetime of the individual (tens of years), the language (thousands of years), and the species (hundreds of thousands of years). Determining the exact weighting of these three components with respect to each other and the nature of their contribution is thus an important issue for future research in the evolution of language.

Vocal versus Manual Origin of Language

Another strongly debated issue in language evolution research is whether language originated as a system of manual gestures or evolved exclusively in the vocal domain. On the one hand, it has been proposed that because vocal communication in primates is largely affective in nature, with little voluntary control, language is likely to have emerged from manual gestures rather than primate calls. In some versions of this account, the emergence of gestural language was predated by the evolution of a unique human ability for complex imitation. The subsequent change from a gestural to a primarily vocal language has been argued to be due to either increased tool use coming into conflict with the use of the hands for linguistic gestures or the 'recruitment' of vocalization through associations between gesture and sound. The close relationship between manual gesture and a subsequently evolved sophisticated ability for vocalization (in the form of speech) is furthermore suggested to have left us with the uniquely human characteristic of right-handedness.

One the other hand, critics of the gestural theory of language origin have argued that manual gestures suffer from two major disadvantages in comparison with spoken language: they require direct line of sight and they cannot be used at night. Instead, several proposals have been put forward to support the possible origin of language in the vocal domain. One suggestion is that the basic structures of syllables derive from the succession of constrictions and openings of the mouth involved in chewing, sucking, and swallowing – eventually evolving into phonetic gestures. It has also been contended that this evolutionary process may subsequently have resulted in the major syntactic distinctions between noun phrases and sentences. An alternative perspective suggests that natural selection for brain structures necessary for the motor activities involved in walking on two legs may have laid the groundwork for the evolution of the neural substrate necessary for speech production and perception, which in turn provided the basis for the emergence of syntax.

Although mathematical and computational modeling may help inform the discussions about the relationship between biological adaptation and cultural transmission in language evolution, such modeling is less likely to be able to address issues related to the origins of language. However, evidence from other disciplines, such as archeology, comparative neuroanatomy, primatology, psycholinguistics, and cognitive neuroscience, may provide clues to an answer, although it is unclear whether this debate can ever be settled completely.

The Nature of Protolanguage

Setting aside the possibility of sharing some or many of the systems underpinning language with other species, it is clear that there is a huge gulf in complexity between the language spoken by any human and the communication used by our nearest primate relatives. For many researchers, this gulf is a problem for any evolutionary account of language. It leads us naturally to wonder whether it is possible to have something that was less than a full human language but more than an animal communication system – an evolutionary 'protolanguage.'

Broadly speaking, there are two different views of what the nature of protolanguage may have been. One approach suggests that protolanguage was 'compositional,' involving simple combinations of meaningful words but with little or no syntactic structure. Alternatively, it has been proposed that protolanguage was 'holistic' in nature, with unanalyzed wholes expressing complex meanings that we today would express using multiword combinations. In both cases, however, it has been suggested that there exist a number of 'living fossils' of protolanguage that we can observe today.

Evidence in favor of compositional protolanguage comes from pidgin communication (the communication system sometimes formed in communities of adults that lack a shared language), child language at particular stages of development, and the language of trained apes. Analyses of these diverse forms of behavior suggest the possibility of an evolutionarily prior form of language that may have shared some features of fully modern language but lacked others. In particular, whereas all three use individual meaningful words, their combination to form utterance meanings involves little or no syntactic structure (e.g., there is no recursive embedding, obligatory propositional structure, or purely structural grammatical elements).

Support for holistic protolanguage can be found in the form of formulaic language, which consists of utterances or parts of utterances in normal language use that appear to be processed completely holistically as unanalyzed chunks rather than syntactic combinations of individual meaningful words. These formulas include idiomatic expressions, such as 'bought the farm' (whose meaning, 'died,' appears to be completely unrelated to its form); certain standard situational utterances, such as 'was there anything else'; and other expressions, such as 'by and large,' whose semantic opacity suggests they are holistically processed. (It is important to note that although the examples of formulas appear to be strings of words, this is simply because they exist within a language that is already syntactic.) Such formulaic use appears to be rampant in normal language use and may thus be seen as a potential key element of protolanguage.

Further differences between these two perspectives on protolanguage derive from different ideas about how full human language may have evolved from its proto-form. Whereas the compositional approach suggests that the change was a biological one, the holistic approach suggests it was driven by cultural transmission. The plausibility of the latter claim has been given some support by computational models that have demonstrated the spontaneous emergence of syntactic structure in populations initially speaking a holistic protolanguage.

Independent of the outcome of this debate, the protolanguage evidence demonstrates the logical possibility of a system of communication that is like language but with some components missing, and it furthermore points to real instances of such a system in the world that are at least partially functional. Theoretically, this points to a possible smooth adaptive pathway from an alingual state to a linguistic one. Moreover, the notion of protolanguage is interesting because it opens up the possibility of 'major transitions' within the evolutionary trajectory of language. It may thus be useful to return to Maynard Smith and Szathmáry's work and seek parallels with other evolutionary transitions to help illuminate the debate.

Conclusion

Since the 1990s, research on the evolution of language has seen rapid growth. This increased research activity is warranted given that an understanding of language evolution may shed much light on human evolutionary history. However, if Maynard Smith and Szathmáry are correct, then language evolution research may also provide important insights into the evolution of life. Thus, the evolution of language constitutes an important challenge for contemporary science. In this article, we provided a brief survey of some of the work being undertaken to answer this challenge, focusing on current trends and controversies. It is conceivable that there will be questions to which we may never find definitive answers. However, it is clear that we will only be able to address the many questions surrounding the evolution of language by taking into account the various systems that underlie it, making this scientific endeavor an interdisciplinary enterprise by necessity.

See also: Language Development; Language: Auditory Processes; Language: Nonhuman Animals; Language: Cortical Processes; Primate Communication: Evolution; Psycholinguistics; Speech Production: Development; Speech Perception: Cortical Processing.

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