16

Cultural Evolution of Language

Dan Dediu, Michael Cysouw, Stephen C. Levinson,
Andrea Baronchelli, Morten H. Christiansen,
William Croft, Nicholas Evans, Simon Garrod,
Russell D. Gray, Anne Kandler, and Elena Lieven

Abstract

This chapter argues that an evolutionary cultural approach to language not only has already proven fruitful, but it probably holds the key to understand many puzzling aspects of language, its change and origins. The chapter begins by highlighting several still common misconceptions about language that might seem to call into question a cultural evolutionary approach. It explores the antiquity of language and sketches a general evolutionary approach discussing the aspects of function, fitness, replication, and selection, as well the relevant units of linguistic evolution. In this context, the chapter looks at some fundamental aspects of linguistic diversity such as the nature of the design space, the mechanisms generating it, and the shape and fabric of language. Given that biology is another evolutionary system, its complex coevolution with language needs to be understood in order to have a proper theory of language. Throughout the chapter, various challenges are identified and discussed, sketching promising directions for future research. The chapter ends by listing the necessary data, methods, and theoretical developments required for a grounded evolutionary approach to language.

Language from an Evolutionary Perspective

Language plays a central role in human cultural life, with thousands of languages being spoken, showing extensive and (from the point of view of other animal communication systems) unexpected variation throughout the world (Fitch 2011). From an evolutionary perspective, a central question posed by this variety of languages is how this diversity arose. Likewise, it is of central importance to elucidate the processes that shaped this variation, and to discover whether these processes differed in the past from what they are today (see, e.g., Baronchelli et al. 2012). Understanding these processes is not only relevant for understanding the history and evolution of languages, it can also

From “Cultural Evolution: Society, Technology, Language, and Religion,” edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

function as a unifying force to draw together the widely dispersed and largely unconnected subfields of contemporary linguistics.

Taking an evolutionary perspective on language raises many questions: Does embedding language evolution within a general theory of cultural evolution produce elegant and effective explanations of linguistic phenomena? Are there rich and detailed laws of cultural evolution that apply universally, and thus also to language, and if so what are they? For example, are there general predictions about population size and rates of change or degrees of complexity? Are there predictions about the minimal size of a population still capable of carrying a quantum of cultural information across time? Or are there implications for competition between human groups and rates of change? At this stage we are not in a position to answer such questions, which constitute part of the ongoing challenge in this domain. However, we would like to sketch the main challenges for an evolutionary perspective to language.

This chapter summarizes a wide range of issues for an evolutionary perspective on language. We begin by sketching a few positions—widespread in linguistics—that are at odds with an evolutionary perspective (see section, The Misconception of Language Particularism). These positions all argue for language being different from other kinds of human culture. In contrast, we will argue that these differences are all just a matter of degree and thus not a barrier to evolutionary thinking. Next, to set the scene, we briefly sketch the current (rather limited) state-of-the-art evidence about the biological origin of language (see section, The Antiquity of Language). Thereafter we turn to the central questions for an evolutionary perspective (see section, Function, Fitness, Selection): What are the functions of language that are under evolutionary pressure? How can we operationalize a suitable notion of fitness? What are the entities of replication, and what are the processes leading to differential replication?

Focusing on more empirical questions, we investigate the current diversity among the world's languages and raise central questions about how to proceed with worldwide linguistic comparisons. Why are there about 7,000 languages in this world, and can we say more about their phylogenetic relationship? Can we develop methods to compare traits of languages, given the wide variety of linguistic structures attested? In addition, given a design space of such traits, what are the preferred routes of change through this space?

On a slightly more abstract level, we proceed to a discussion of the shape (the extent to which human language is tree-like) and fabric (the extent to which traits of language develop as bundles) of human language evolution. In this context we also briefly discuss the influence from language ontogeny on language phylogeny (for further discussion of developmental issues in cultural evolution, see Appendix 1).

A central tenet of the evolutionary perspective is that language is not isolated from biological and social evolution. Therefore, we discuss the ongoing processes of biological, social, and linguistic coevolution. Finally, we

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

highlight some of the most pressing further developments that are necessary to bring the field forward. Throughout the chapter, we identify challenges for future research that succinctly summarize some of the main issues that came up during our myriad discussions.

The Misconception of Language Particularism

An alternative nonevolutionary position, still widespread in linguistics, holds that language is a domain that has such special properties that there is no reasonable expectation that general laws of cultural evolution would apply in a uniform way across language and other contrastive domains like religion, technology, or group organization (Pinker 1994). Below we list a number of apparent reasons for thinking that language is apart and special, together with the reasons why these can be discounted. Note that it is not so much the following assumptions themselves which are misconceptions, but it is a misconception that they differentiate language from other aspects of human culture. Also note that the following misconceptions, when accepted, suggest that an evolutionary approach to language is useless. Through this lens, language would be a uniform phenomenon through time and space, and the only way it could have arisen is through a catastrophic change (e.g., Chomsky 2010).

Misconception 1: Language Is Biologically Fixed

Although we agree that language has a deep biological evolutionary background (see sections, The Antiquity of Language and Coevolution of Biology, Culture, and Language), reflected superficially in the specific physiology of the vocal apparatus and potentially in certain brain specializations, we do not think that this deep biological background is special for language. Human technology can equally be seen as reflecting the anatomy of the hand (Shennan, this volume; Stout, this volume). Likewise, group organization and religion are guided by innate behavioral dispositions (Haun and Over, this volume; Whitehouse, this volume).

Misconception 2: Language Changes Constantly

There is a recurrent assumption in linguistics that language changes incessantly, without any direction or advancement (Battye and Roberts 1995; Lightfoot 1999). Indeed, rates of change in language are relatively uniform and constant compared to, say, technology, where technological change shows rapidly accelerating rates of advance. Again, this apparent difference can be eroded, with the caveat that we have no precise way to equate rates of change across domains. Some aspects of language, specifically phonetics/phonology and the lexicon, can change at very fast rates, and it seems better to think of

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

language as structured networks of relations where deep hubs may be resistant to change, while surface nodes can react swiftly to surrounding forces (e.g., Dediu 2011a).

Misconception 3: Every Human Has Full Command of Language

Language exhibits population saturation: every normal person acquires languane over the initial childhood years such that they appear to command language in a way that is not true for technological or religious expertise, for example. Here we are caught in two fictions, widespread in linguistics and psychology: (a) children have full command of their language by three (or seven, or eleven; Crain and Pietroski 2002), and (b) all adults have comparable language competence.[1] In fact, language acquisition continues through the active adult years, as new rhetorical skills and new social arenas are mastered, such as the acquisition of the "triangular" kin-term register in Bininj Gun-wok, which continues into a person's twenties (Evans 2003a). In addition, there are substantial individual differences in almost all aspects of language (e.g., Street and Dąbrowska 2010; Farmer et al. 2012).

Misconception 4: All Languages Are Equally Complex

This misconception arose with good reason at the start of the twentieth century to counter Eurocentric notions of language structure, but it is currently widely accepted that there are differences in structural complexity between languages (e.g., Sampson et al. 2009; McWhorter 2011). However, when there are differences in the complexity between languages, language complexity is often assumed to show reverse patterning to, for example, technological complexity in response to demographic variables: high degrees of morphological complexity in language are mainly found in small-scale societies (Lupyan and Dale 2010), whereas high degrees of technological complexity are primarily found in large-scale societies (Trudgill 2011; Shennan, this volume). Still, once again, careful consideration shows the mismatch to be ill conceived, because languages spoken in technologically complex societies have substantially larger lexica, owing to such factors as occupational specialization (allowing different individuals to have differently elaborated specialized vocabularies) and the elaboration of vocabulary needed to describe the attendant technological complexities. Pawley (2006), who attempts to establish ballpark figures for the size of the lexicon of unwritten languages, finds a range from 5,200

[1] As an example, see Pinker (1994:18): "Language is a complex, specialized skill, which develops in the child spontaneously, without conscious effort of formal instruction, is deployed without awareness of its underlying logic, is qualitatively the same in every individual, and is distinct from more general abilities to process information or behave intelligently"; see also Nowak et al. (2001).

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

(Nunggubuyu) to 31,000 (Wayan Fijian) for 16 languages of Australia, New Guinea, and the Pacific. These are one to two orders of magnitude smaller than the English figures of 460,000 as represented by Webster's Third New International Dictionary or, for the 1933 Oxford English Dictionary, 252,259 entries and 414,825 defined words (headwords and subentries).[2] Once we take into account all the linguistic levels, and use more sophisticated measures of complexity (Bane 2008), it is unlikely that the patterns in language evolution are the inverse to technology evolution.

Misconception 5: Biological Evolution Is Independent of Language Change

When thinking about language evolution, there is a recurrent assumption that there is a clear-cut difference between emergence of language and subsequent language change (e.g., Pinker 1994; Berwick et al. 2013). Confusingly, these two phases are both referred to as "evolution" in the literature. However, this perspective assumes that there are different processes at work in the phase when modern humans separated from other primates compared to more recent processes leading to language change over the last few thousand years. Now, given the enormous difference in the amount of time that these phases encompass (in the order of millions of years in the first case, compared to an order of thousands of years in the second phase), it is not surprising that there are differences between them. However, as a general approach within the evolutionary perspective, it seems much more profitable to assume a general continuous development throughout the whole history of language with differences in degree, but not in quality (while remaining well aware that "more is different" in complex systems; Anderson 1972). An important correlate of this assumption of continuity is that biological evolution and cultural evolution are both ongoing, and there is interaction between the two (see Levinson and Dediu, this volume). It is not the case that biology is an invariant on the basis of which cultural variance can develop. Both biology and culture are sources of variation and constancies, and change is ongoing in both. Biology might be more "stable" than culture in the sense that changes normally proceed more slowly in biology than in culture, but this is likewise a difference in degree, not in quality.

[2] Many factors complicate the interpretation of these figures, so they need to be taken with caution. Such factors include (a) likely less substantial documentation with some of the languages in Pawley's sample, as compared to English, (b) the effects of morphological type—each Nunggubuyu verb can have hundreds of inflected forms, compared to just four for most English verbs (e.g., *kiss, kisses, kissed, kissing*), (c) the question of whether we are comparing the vocabularies of individual speakers (which may display much less variation) or the summed vocabularies across a whole society (which could differ much more once there is occupational specialization), and (d) the fact that dictionaries of written languages will preserve many words no longer in active use.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

The Antiquity of Language

Human languages present a special opportunity for the study of cultural evolution. There are many of them—around 7,000—allowing (in principle) the testing of hypotheses over large populations of sample points, if we compare this to the slim set of data points in lots of archaeological settings, for example. Although our coverage is still nowhere near enough—with something like reasonably sophisticated coverage for only around 20%, and languages becoming extinct at an accelerating rate—we have an increasingly convergent idea about what needs to be done to get good coverage (although the bar for what gets counted as good documentation is constantly being raised). From a data-collection point of view, the complexity of languages—unlike, say, technologies—is of a comparable order of magnitude for all the world's cultures (although the distribution of complexity may vary with community size; Lupyan and Dale 2010).

We know incredibly little about the emergence and early evolution of language in our lineage. Modern humans seem to be at least 200,000 years old (Klein 2009). The split between modern humans and the Neandertal/Denisovan lineage can be dated around 500 KYA (Hublin 2009; Green et al. 2010), and the even earlier *Homo erectus* dates to about 1.8 MYA. The evolution in *FOXP2* (Krause et al. 2007; Green et al. 2010) and breathing control (MacLarnon and Hewitt 1999) may be positioned in the transition between 1.8 and 0.5 MYA. The premodern human audiogram from about 600 KYA appears to be similar to ones from modern humans (Martínez et al. 2004, 2008b). It seems that the Neandertals adopted modern human technology (Floss 2003), and that several modern human cultures left archaeological records strikingly similar (or even simpler) to those of the Neandertals (Roebroeks and Verpoorte 2009). So, there is circumstantial evidence that modern-like language could have been around half a million years ago, and that the Neandertal/Denisovan lineage would have been using some form of language (Dediu and Levinson 2013). Further, when we strictly distinguish between language and communication, it seems to be quite possible that successful communication was available millions of years ago.

Linguists generally take the time barrier for reconstructable clades (language families) to be around 8–10 KYA (e.g., Renfrew et al. 2000). This limitation leaves us with lots of unconnected language families (a couple of hundred) and no deeper phylogeny. It also makes it difficult to harness data from the number of maximal clades and reason back from this to the antiquity of language as a whole. However, there are parts of the world which, when plugged into the overall picture, suggest considerable antiquity. In the Australian case, we have a single continent, inhabited for at least 40,000 years without any major discontinuities suggesting more recent immigration (see, however, the recent finding of an Indian genetic connection about 4,000 years ago; Pugach et al.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

2013), and for which all the languages appear to be related at a deep level (Evans 2005). Do we have a 40,000-year-old language family in this case? It may, of course, be that the oldest common ancestor to all modern Australian languages is more recent than this as a result of lineage death for higher-order branches. Nonetheless, it is not implausible to see Australian languages as descended from whatever language was spoken by the first humans to arrive in Australia. Australian languages represent, however, only a tiny fraction of the world's total phylogenetic language diversity. This seems more consistent with an earlier (250,000 years or older) than a later (80–100 thousand years) date for the origins of human language.

There are various proposals in the literature for higher-level groupings such as "Nostratic" or "Amerind," but these are currently not well supported by the available evidence (Renfrew and Nettle 1999). A way forward could be represented by methods which combine multiple sources of linguistic evidence so as to estimate abstract properties of language change, which may be able to break the 10,000-year barrier (Dediu and Levinson 2012).

Challenge 1: To What Extent Do Communication, Language, and Speech Have Separate Evolutionary Histories?

In normal language production, the face, the hands, and the nonverbal paralanguage are all coordinated to produce an overall message. In human development, however, these are dissociated, with early nonverbal communication (smiling, vocalizing) preceding pointing, which itself precedes the first words. It seems not unlikely that during the phylogenetic development of human communication there was a similar dissociation, with general communicative abilities preceding language proper. Nevertheless, in modern human language production, hand and mouth seem coupled, with the emphasis reversible (as in sign languages), suggesting that change may have occurred more in the general weighting of the modalities than in their incremental addition. There are suggestions that speech was essentially modern at least 0.5 MYA (Dediu and Levinson 2013).

Function, Fitness, Selection

Here we investigate some of the central questions for an evolutionary perspective. This involves the functions of language that are under evolutionary pressure, the notion of fitness, and the entities and processes involved in selection.

Function

From an evolutionary perspective, it is necessary to clarify the function of an entity that is under evolutionary pressure. Language is generally considered

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

to be a device for exchanging information, or for the expression of meaning. However, the concepts of "information" and "meaning" are both ill defined. Information is such a broad concept that almost everything can be considered as information. Meaning is a quality that we obviously share with all of humankind, but it is intrinsically impossible to draw out of our minds other than by using language itself.

The different functions of language have been much debated (for a classic account, see Jakobson 1960). Here we emphasize two functions of special relevance to the discussion of language evolution: (a) the role of language to coordinate joint action (including acts of transmission of knowledge) and (b) the role of indicating social relationships. The coordinative role places language use firmly in the class of coordinative social phenomena, with consequences for its temporal stability and resistance to unilateral innovation (e.g., Tomasello 2008). The role of expressing and manipulating social relationships is another possible force for language differentiation, especially as ethnic markers (Boyd and Richerson 1987a) or with a "shibboleth" function (Cohen 2012) as costly signals of in-group membership. People are masters of picking up such linguistic cues rapidly and consistently, allowing language to affect social structuring.

Being a form of coordinative technology, language has a "parity problem"; that is, it works only if we agree on the joint code. However, this problem is not special to language, but is shared by all systems of cultural evolution that have a significant "coordinative" element, which are essentially games of pure coordination. All social rules and norms are of this kind: consider driving on the left- versus right-hand side of the road, or wearing your shield on your left hand in phalanx formation, or singing in unison in a religious ritual. The cultural evolution of language thus falls under all the general laws that apply to coordinative social domains (Chater and Christiansen 2010). Such domains do not include, for example, competitive arenas, where doing precisely what the others do not do may confer significant advantage (e.g., betting against the market, playing tennis or bowling with the left hand, inventing a new kind of fishing fly). A question for future research is whether there are common properties of coordination systems that hold across language, group formation, and religion, but also whether there might be properties unique to language as a cultural system for coordination, due perhaps to the complex multileveled structure of the system.

A central question that emerges from these two main functions (coordinative transmission of knowledge vs. marking social relations) is whether language was evolutionarily designed for one of these two functions, and whether the other was originally an exaptation with only secondary selective pressure. Such questions might sound highly speculative, but they may be profitably transformed into testable hypotheses. Given the approach taken by Cohen (2012), which examines the role of accent as a group marker, all features that mark group membership might be expected to be less strongly expressed in

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

small communities. Another hypothesis is that groups under demographic pressure should show more schismogenetic effects (i.e., traits that are marking differences should proliferate). For example, variation in phonetic realization and intonation ("accent") seems to be a highly prominent social signal of language, as opposed to grammatical structure which stays much more "under the radar"' as far as conscious manipulation by speakers is concerned. This leads to the hypothesis that groups under demographic pressure should show high rates of phonetic change as opposed to grammatical change.

Fitness

Any mention of language function immediately raises the question of what the metric of fitness should be for an evolutionary model of language. Here there are no simple answers, since there are at least three different levels of language fitness to be distinguished: user fitness, group (and whole language) fitness, and item fitness. The relation between these different kinds of fitness (i.e., whether some of them are more fundamental than the others) is an important question for further debate (see next section).

First, from the perspective of a language user, language skills—like eloquence in speaking or writing—may translate directly into biological fitness (but this is an area ripe for further investigation). Rhetoric and persuasion play an important role in leadership qualities, and leadership may in specific social circumstances correlate with potential for increased offspring. A speaker that is able to master more languages or "accents" (something that is difficult for most people to achieve) will be able to reach more people. In addition, the cooperative exchange of information in undertakings important for survival, and in linguistic exogamy, may likewise confer biological fitness advantages, making traits like multilingualism and the ability to express oneself concisely in a biologically relevant way.

Second, from the perspective of group fitness, particular linguistic design choices may impact on issues like the scale of the unified speech community, translating into scale of polity. A classical example is the way written Chinese, by transcending phonetic particularity, has allowed communication across the world's largest polity and its cultural outliers, as well as across time through ancient texts over millennia, contributing to the extraordinary cultural continuity of Chinese civilization. This works because the same character can express the same meaning despite different sounds, both in different Sinitic languages like Mandarin or Cantonese as well as in other unrelated languages of the Sinosphere like Korean or Japanese.[3] As Ostler (2005:157) states: "No

[3] For example, the character 山 for mountain, is pronounced *shān* in Mandarin, *saan1* in Cantonese, *san* in Korean and *san* or *yama* in Japanese, or 中 for middle, is pronounced *zhōng* or *zhòng* in Mandarin, *zung1* or *zung3* in Cantonese, *chung* in Korean and *chuu* or *naka* in Japanese.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

alphabetic script, based perforce on the sounds of a language, could now be so conveniently neutral in terms of all the different Chinese dialects."

Phonetic writing systems, on the other hand, need to track the inexorable effects of sound change, so that the written forms of the various Romance languages, for example, despite having a common ancestor around the same time as the Sinitic languages, are not mutually comprehensible across speakers of different Romance languages in the same way as in Chinese. In addition, languages get associated with ethnic identities, and where the viability and desirability of such group identification is lost, language shift typically takes place.

Third, when we take the perspective of the linguistic item, its chances in differential reproduction may depend on its value by association with a prestige group (as in the adoption of accent or fashionable phrases) and the degree to which it is unencumbered by systemic constraints (thus a noun is easier to borrow than a verb, a content word easier than a function word or affix). This perspective is elaborated in more detail below.

Replication and Selection in Language Evolution

A cultural evolutionary approach to language change recognizes that there are two interconnected processes: (a) the generation of variation via descent with modification and (b) selection operating on that variation. Indeed, this is a basic prerequisite to describing cultural change as evolutionary (Darwin 1859). In the case of language change, cultural evolutionary processes give rise to lineages of languages and of linguistic structures (such as sounds, words, and constructions), and methods used in biology to reconstruct lineages can be applied to language change (e.g., Bouckaert et al. 2012). Several proposals have been made for a more specific model of causal relations between variation and selection, and the entities that are involved in biological and cultural evolutionary processes.

One influential model that has been applied to cultural evolution is Dawkins's "selfish gene" (Dawkins 1976, 1982). Dawkins generalizes the role of a gene to a replicator, focusing on the copying process involved in descent with modification. He also proposes that cultural replicators (the so-called "memes") exist and that they evolve in the same way that genes do. Dawkins's theory of replicators is part of a general theory of "memetics" (Blackmore 1999), which proposes that only genes are replicators in biological evolution, that they are the units of selection, that organisms are mere "vehicles" for genes/memes, and that cultural meme replication and selection is analog to biological parasitism. This more general theory, in our opinion, has generally not been successful in providing novel insights into cultural evolution (for an application of memetics to language change, see Ritt 2004).

Beginning with Dawkins's concept of replicator and the lineages that replicators form, Hull (1988, 2001) constructs quite a different general model

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

of biological and cultural evolution. Hull treats the replicator as a role that can be filled by any entity that fits his definition of replication and introduces another role (the interactor), also potentially filled by many entities. Unlike Dawkins's vehicle, Hull's interactor plays a significant role in selection. Croft (2000) uses Hull's model as the starting point for a cultural evolutionary model of language change in which speakers and the utterances they produce each play significant roles in the linguistic evolutionary process. Baxter et al. (2006) developed an agent-based model based on Croft's theory that has been applied to issues regarding propagation (selection) of linguistic variants in sociolinguistics (Baxter et al. 2009; Blythe and Croft 2012). A number of important issues remain in treating a model of cultural evolution such as Croft's as an instance of a general evolutionary model.

Replicators are extremely difficult to identify in biological evolution. There is no simple relationship between a "gene" and the DNA molecules that actually undergo the physical copying process in biological evolution. A single "gene" may be distributed across multiple discontinuous sites in the genome; the sites for two "genes" may overlap or even be identical (the different "genes" being read differently); "genes" may interact with each other in complex ways such that they form a network functioning as a unit; and so on. Thus, the status of a "gene" as a unit independent of the DNA sequences that contribute to it is unclear. "Genes" are often individuated in terms of their relationship to the phenotype, namely as an instrumental (Griffiths and Stotz 2006) concept in modeling the transmission of a heritable phenotype. However, the past few decades have demonstrated that this relationship between genotype and phenotype is very indirect and complex. The phenotype is strongly influenced by developmental processes, and the interaction of the developing organism with its environment is essential. These new insights in understanding biological evolution are leading to dramatic changes in evolutionary theory, with various proposals of extension such as the so-called ecological evolutionary developmental biology, or "eco-evo-devo" (e.g., Jablonka and Lamb 2005; Gilbert and Epel 2008; Jablonka and Raz 2009; West-Eberhard 2003; Koonin 2012).

It is unclear what the consequences of these developments will be for replicator-based models of cultural evolution. Intriguingly, there are analogs in language to these more complex phenomena in biological evolution. For example, linguistic units which form lineages include other lineage-forming units (e.g., constructions include words, and words include sounds); constructions may form discontinuous parts of utterances; linguistic units interact with one another in such a way that they form a unit. Linguistic units are also individuated instrumentally, in terms of their function in the linguistic system and in communication, and there are many complex issues as to how the linguistic system is constituted and how linguistic communication takes place. These phenomena suggest that linguistic evolution and biological evolution do share basic features.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

In addition to these issues in biological and cultural (including linguistic) evolution, a second problem in cultural evolution is what sort of cultural entity replicates. Various scholars have proposed that concepts, cultural behaviors, or artifacts may function as replicators. It remains to be seen whether any, all, or some combination of these entities are reasonable candidates for cultural replicators.

Despite these theoretical problems, research that applies phylogeny reconstruction techniques from biology to language change have been productive, as have evolutionary agent-based models of language change to issues in language origins and the propagation of linguistic variants in a speech community (for a discussion, see Hruschka et al. 2009). How much further such methods and models from evolutionary biology can be applied to language change, and to what extent such applications will help us in understanding cultural evolution as a general evolutionary process, is a major question for the future.

Challenge 2: Can We Identify the Signature of Mechanisms for Generation of Variation and Selection in Language Evolution?

It is generally agreed that evolution involves two processes: the generation of variation and selection operating over that variation. A wide variety of mechanisms of language change have been proposed by linguists for these two processes. One set of factors are cognitive, including the phonetic (articulatory and auditory) motivation of sound change, analogy, frequency-driven factors (e.g., the shortening of linguistic forms: "cellphone" to "cell" or "going to" to "gonna"), meaning, pragmatics, discourse interaction, and relations between units in the linguistic system (see Keller 1994; Croft 2000). A second set of factors are social, including network structure, the structure of adopter groups, and social valuation of linguistic variants. Given the wide variety of factors that have been proposed for both the generation of variation and selection, how can one distinguish them in terms of effects on language evolution? Is it possible that different types of factors leave an identifiable signature in language change?

Diversity

Cladogenesis: Why Are There 7,000 Languages?

Why is there not just one single world language, or alternatively, why are there not 2.8 million different languages (the figure we would get if we extrapolated the ratio of languages to speakers in Vanuatu to the rest of the world)? Why is there a high-language density in some regions of the world, whereas in other areas only a very few languages are spoken?

To address such questions, we need a better understanding of cladogenic processes (i.e., processes that lead to the split up of languages into various

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

daughter languages). Many factors appear to be important for the process of cladogenesis in linguistics: First, the density of the population itself might influence the process, in the sense that the availability of empty niches allows for the rise of separate groups. Second, the general tendency of humans to divide humanity into in-group–out-group oppositions is a force to develop different languages. The widespread practice of exogamy is a special case of this, because for exogamy to be feasible, group opposition is necessary, and linguistic diversity seems to be a primary way to enhance such an opposition (Sorensen 1967; White 1997). Third, the human capacity to maintain cohesive groups appears to be limited (e.g., Dunbar 1993), so split-ups are inevitable to some degree. Fourth, Nettle's (1999) proposal for the latitudinal asymmetry (there are more languages around the equator) is that there is a longer mean growing season in this area, leading to the possibility for smaller self-sufficient group sizes, and consequently for the possibility of smaller groups and more languages. Finally, multilingualism is important in altering the selective process in two key ways: (a) it acts as a conduit for replicators to pass between speakers of different languages and (b) it extends the range of interactors for whom signs carry social-affiliation information to a broader speech community.

Still, most potential factors and explanations for language diversity and skewed patterns of language cladogenesis are strongly under-investigated. It is unclear why there has been reluctance in linguistics to investigate such pressing questions further. Nevertheless, there are some early indications that language splits are somehow special, in the sense that both the basic vocabulary (Atkinson et al. 2008) and structural features (Dediu and Levinson 2012) show punctuated evolution, change in both being accelerated around language splits.

For the future, we see two main desiderata for the study of these issues. First, at the macro level there are questions regarding the global prediction of linguistic diversity based on political, ecological, cultural and social structure. For such research, we need large global databases, along the lines of the World Atlas of Language Structures (WALS),[4] and the Human Relations Area Files (HRAF).[5] However, the data currently available is far from ideal and can only be taken as provisional. In contrast, at the micro level, there is a need for detailed sociopolitical studies of multilingual situations to establish models of the processes that are happening in interaction. We lack, for instance, field studies of the processes involved in language differentiation (e.g., during the breakup of Yugoslavia or the tribal conflicts of the Sudan or Somalia). Such studies could then be used to inform simulations, which need detailed knowledge of the relevant variables to be successful.

4 http://wals.info/

5 http://www.yale.edu/hraf/

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

Challenge 3: How Does a Theory of Language Diversity Look?

There are at least two aspects to language diversity: the number of languages and the overall amount of variation between languages (disparity in biological terms). To date there is no formal theory about what drives either the rates of linguistic diversification (cladogenesis) or the rates of linguistic disparity (anagenesis). Linguistic cladogenesis is produced when speech communities split, and thus factors which promote group boundary formation are also likely to produce more languages. Possible factors include migration, environmental heterogeneity, increases in population size, and selection that favors some groups over others. Possible factors that drive disparity include group size, social networks density, contact with other languages, and the social processes of schismogenesis (esoterogeny). What we need now are formal theories of the relationships between these variables.

Challenge 4: Can We Build a Global Tree of All Known Languages?

A complete understanding of the complex historical relationships between the world's languages would be a major scientific advance. More importantly, it would provide a backbone on which many more specific questions could be meaningfully asked, such as the relationship between various components of language and culture and their rates of change. Although such a project is conceptually simple, it faces two main problems: First, the rate of linguistic change is such that most historical linguists believe that any genealogical signal is obscured by chance and borrowing beyond a 10,000-year time depth. Although there are some suggestions that highly conserved items of basic vocabulary and some structural features might retain historical signal beyond this, the prospect of rigorously inferring language relationships right back to "protoworld" or the African diaspora of modern humans seems remote. Second, it is not a priori clear whether a tree-like model would be sufficient, given the extent of horizontal processes in language. The hunt for a global tree of languages might end up as tangled as the hunt for the tree of life.

How Does Cultural Evolution Explore the Design Space of Languages?

When studying human language, one of the central questions concerns the possible structural variation: How large can it be, and what constraints are acting on it? It is useful to introduce the notion of a "design space," which can be characterized in terms of the ranges of variables, bounded by the parameters of a domain, within which a design solution must be found. Two different approaches can be taken to address this question about the nature of the design space for human language (see Evans and Levinson 2009a; Levinson and Evans 2010). First, the a priori question (necessary to be able to study

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

linguistic variation in the first place) is what kind of design space can we use to describe language variation? Here, the problem is that there is no easy external “measuring stick”’ with which to compare languages. Second, given an a priori grid of possible variation, how does the actual a posteriori variation of the world’s languages look?

The large set of data points afforded by thousands of languages, as well as the possibility of setting up frameworks of comparability able to make unified categorizations despite very significant differences in how languages work, opens up possibilities for many types of hypothesis testing. A key part of doing this is setting up a comprehensive, precise, and operational ontology of the design space—or, perhaps more realistically and slightly less ambitiously, of the multiple design spaces found for each relevant variable in phonology, morphology, syntax, semantics, and so on (as well as in such other areas as register and other sociolinguistic distinctions). The subdiscipline of linguistic typology has been steadily doing this over the past half-century, although the number of dimensions that well-known databases such as WALS cover is only a tiny fraction of the full set, and new dimensions continue to be discovered (e.g., grammatical encoding of speaker and hearer attentional phenomena, in such subsystems as demonstratives and verbal inflections). Categorization decisions continue to dog this enterprise. We see three main ways for the field to break out of the current impasse of the arbitrariness of cross-linguistic categorizations:

1. Switch to continuous rather than discrete variables (e.g., time measurements of voice onset time as opposed to a simple ± voicing contrast).
2. Break down higher-level categories (e.g., “subject of”) to lower-level ones (e.g., “argument triggering verb agreement”).
3. Use direct comparisons of (parallel) texts (allowing multiple values to surface in the one language, measured with respect to the statistical occurrence of different choices) as opposed to grammatical descriptions in which structures tend to be essentialized.

Thinking about the structure of this design space, various issues must be considered. First, is the design space tractable; that is, when looking at extant languages, can we determine the design space of language? The design space of the whole of language may not be tractable, given the number of variables and parameters which must be modeled; however, restricted domains seem to be within our grasp. For example, the tradition of linguistic typology (as exemplified by the WALS database) attempts to survey specific parts of linguistic structure and classify the variation attested in these domains. Although such investigations are far from unproblematic or conclusive, it would appear profitable to map out the possibilities of linguistic structures within restricted domains.

Second, is the design space immutable or changing? Namely, can we assume that the design space of our earlier ancestors was the same as ours and, if not,

From “Cultural Evolution: Society, Technology, Language, and Religion,” edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

in what respects did it change? Can, for example, advances in other cultural systems (e.g., the invention of writing or of information technology) change the design space by making whole new dimensions possible or altering existing ones (e.g., literacy affords increased complexity in both the lexicon and in complex syntax; Karlsson 2007)? Would such changes simply extend existing dimensions, or add to them, or might the topology and metric properties of the space also change? The latter would imply that the "closeness" between language states could change, allowing different evolutionary pathways for language change. Thus, if the design space has this dynamic aspect, it could be possible that changes which did take place in the past might seem implausible today, or more likely that changes today (spurred by literacy and telecommunications) would not have taken place in the past. If the design space is indeed dynamic, a new dimension of complexity to language comparability and language evolution will be added, and computational modeling will have to play a major role in understanding it.

A third, and related, question concerns the reconstruction of the path a particular language has taken through the design space and of the possible paths and associated probabilities that it could have taken. This requires an understanding of the constraints and metric properties of design space acting at each point in this space and possibly their dynamics (see above). To achieve this, we will need much more data on the actual paths languages have taken (e.g., using phylogenetic methods) and of the properties of language learners presented with certain constructions (e.g., using natural and artificial language learning paradigms combined with computational modeling).

Modeling a possibly correlated random walk through the design space could lead us to theoretical expectations of the distribution of languages under different biases to which we then can compare the observed distribution and infer how likely it is that a certain evolutionary hypothesis could have produced this distribution. Similarly, such a theoretical approach could be informative about the fraction of the design space covered under different hypotheses, and could fruitfully be used to explore the dynamic nature of the design space by altering its metric properties following cultural or biological innovations. Moreover, even the dynamics of the landscape exploration could depend upon time and be heavily influenced by the previous history of each language. Computational modeling, for example, suggests that linguistic categorization in isolated populations might correspond to a metastable state where global shifts are always possible but progressively more unlikely, and the response properties depend on the age of the system itself (Mukherjee et al. 2011). The system actually "freezes," spending progressively more and more time in local minima of the landscape (Mézard et al. 1987). In this general scenario, shared linguistic conventions would not emerge as attractors, but rather as metastable states.

Setting all these complexities aside, and assuming we can in fact set up a maximal design space, what can we do with it? First, we can observe the

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

distribution of data points across it. What we tend to find is a crowding in one corner—vast tracts of the design space are empty (e.g., words which mean father or mother's brother, but not father's sister) or only sparsely populated: of the six basic orderings of subject, verb, and object, three (SOV, SVO, and VSO) account for 96% of the world's word orders; the object-initial order (OVS and OSV) are rare enough that they were believed not to occur at the time Greenberg wrote his seminal paper on word-order typology (Greenberg 1966), though the latest WALS survey gives summed figures for these two orders of just over 1% (Dryer 2011). This has driven many sorts of investigation of why particular options are rare. A maximal view of the explanatory challenge would be that for every asymmetry in populating the design space, some explanation needs to be sought, whether in some form of selector bias or as a fossilization of particular design choices in the past (i.e., as attesting to inheritance from some deep ancestor) or accidents of history. It is also important to remember that given the short timescale in which modern humans have spread across the world, there simply has not been sufficient time for cultural evolution to explore the space: languages may fall into a corner for no greater reason than that is where the space began to be explored (Evans and Levinson 2009a).

Second, we can also ask whether the population of the design space has always exhibited the same distribution; for example, was it different in the early phases of language evolution (e.g., the "non-doubly articulated" portion is currently empty except for recently evolved village sign languages [Sandler et al. 2011] but may have been populated in early phases of language evolution)? All modern languages include a number of design elements, but it is entirely conceivable that in an early phase of linguistic evolution, different human groups developed different elements from this list, and these were transferred horizontally between groups to form an integrated "language package." For some of these elements there are temporal dependencies; for example, well-developed intention-attribution (driving pragmatic enrichment of what a sign means) must have preceded the conventionalization of code. For other elements it is quite plausible that they were produced independently, in different groups; for example, developing the notion of abstract property concepts (big, green) independently of what they are applied to (big elephant, green leaf) is logically independent of developing a pronoun system. Thus a plausible coevolutionary scenario for language origins is that different groups made different "technological" breakthroughs in evolving early language systems, these were then picked up by other groups, and the resultant package was so efficient and advantageous that it fed back into biological selection (e.g., vocal tracts favoring fine articulatory movements would have been more and more favored as phonologies became more complex). At the level of more specific properties (say, particular patterns of case marking or types of consonant inventory), was their distribution different when all humans were hunter-gatherers?

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

Finally, we can seek other "external" factors—genetic, cognitive, social/demographic (e.g., group size)—and ask if they correlate with particular design choices (e.g., Ladd et al. 2008).

Challenge 5: Can We Formulate a Total Design Space That Can Serve as a Basis for Worldwide Language Comparison?

What are the units of comparison across languages and how do we best deal with the fact that phenomena do not match up exactly? This is part of the ongoing task of linguistic typology (see Evans, this volume). An important question is whether the design space has remained constant through time or gradually developed new properties. Further, what is the shape of the design space? Another issue is what constraints exist on pathways of movement through the design space: Can individual design states simply move to any other state (unlikely), or are there particular pathways between states? Some progress has been made on doing this systematically with approaches like evolutionary phonology (Blevins 2004). Extending this to a wider range of phenomena is one promising way of developing new methods for obtaining deep-time phylogenies.

The Shape and Fabric of Language

Two important questions in understanding cultural evolution concern the shape of cultural history (the extent to which it is tree-like) and its fabric (the unity of that history). Proponents of cultural phylogenetics are often accused of assuming that human history has been both highly tree-like and consisting of tightly linked lineages, but there are obvious exceptions to these assumptions. We suggest, however, that such highly polarized discussions distort a much more complex reality better conceptualized as involving positions along continuous dimensions. The key challenge is to quantify empirically where particular aspects of culture and language lie on these dimensions, and we believe that current computational methods derived from evolutionary biology coupled with computer simulations are able to address these questions meaningfully. A consequence of this approach is that various components and subsystems of language and culture (such as the basic vocabulary or structural features) might show differing amounts of tree-like evolution and degrees of coherence in different parts of the world and language families.

In this vein, another intriguing parallel can be drawn with evolutionary biology, this time with the unicellular "prokaryotes" and the viruses. The evolutionary history of multicellular organisms can be quite accurately represented by species trees, as the histories of their individual genes[6] tend to

[6] We will not go here into the details of what a gene is, but just use this as shorthand.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

coincide. There are, however, cases of nonvertical inheritance as well, where the history of some genes is decoupled from that of the containing organisms (Arnold 2008; Keeling and Palmer 2008). In the world of microorganisms, these so-called *horizontal genetic transfer* (HGT) phenomena are very important, as they have the capacity to incorporate foreign pieces of DNA and there are mechanisms adapted for transferring genetic material between organisms (Harrison and Brockhurst 2012; McDaniel et al. 2010).

This "rampant" HGT has led some researchers to propose that the metaphor of the "tree of life" might not reflect the biological reality (e.g., Doolittle and Bapteste 2007; Koonin 2009). The fundamental issue is that while each individual replicator (e.g., gene, lingueme) has a tree-like, vertical history, these histories might fail to coincide. In extreme cases of widespread disagreement, one could still reconstruct an agreement tree, but this "tree of one percent" (Dagan and Martin 2006) might not represent anything real. Other methods propose to reconstruct a "forest of life" and try to identify major trends within it (e.g., Puigbò et al. 2009), or use various types of phylogenetic networks (for an application to language, see Nelson-Sathi et al. 2011). However, despite this, there are coherent systems of genes which probably represent stable islands of fitness maxima, and not all genes are equally prone to HGT—those that are hubs in complex gene networks or are involved in the "informational" aspects of cell functioning are more resilient (the "complexity hypothesis," Jain et al. 1999). Thus, the potentially enormous sea of combinations due to HGT is in fact sculpted by natural selection, resulting in stable "bundles" of genes that are optimally integrated and stable through time, forming coherent lineages.

Similar processes might be at work in language: despite the maximally diffusionist position (e.g., Thomason and Kaufman 1988) that virtually anything can be borrowed between languages, there nonetheless appear to be stable lineages of traits, such as morphological paradigms, that we can use as coherent and stable subsystems. Moreover, recent phylogenetic work strongly suggests that at least the basic vocabulary tends to be inherited as a coherent unit (Pagel 2009; Gray et al. 2010; Bouckaert et al. 2012), and even important amounts of borrowing among languages can be detected by such methods (Currie et al. 2010b).

Pulling in the opposite direction, a widely held belief among linguists is that language is a system where "everything hangs together," whose system coherence means that changes in some feature (e.g., order of basic clause constituents, or the height and frontness of one vowel in the space) will pull along changes in some other features (e.g., order of adpositions with respect to nouns and of relative clauses to their heads, or of the realizations of other vowels). As more evidence from a greater range of languages has accumulated, an increasing number of these correlations turn out to be probabilistic rather than absolute. This reflects common preferences for processing (Hawkins 1994) or historical links between how some categories (e.g., adpositions) derive from

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

others (e.g., verbs or nouns), which means that some of the claimed word-order correlations may be lineage specific rather than universal (Dunn et al. 2011b; cf. Croft et al. 2011).

Challenge 6: What Are the Relative Contributions of Vertical and Horizontal Processes in Language Evolution?

Much recent work on the cultural evolution of language—especially, but not exclusively, in terms of modeling (for a review, see Jäger et al. 2009)—has focused on either vertical transmission of linguistic structure across generations of language learners or horizontal transmission of linguistic elements through interactions between language users. Both lines of work have suggested that biases in cultural transmission can lead to the emergence of language-like structure from a starting state without such structure. However, relatively little work has sought to investigate the two types of transmission within a single framework. Further, we know relatively little about what the relative contribution of vertical and horizontal transmission is in language evolution from an empirical perspective (Gray et al. 2010). More generally, we lack a theory about the interplay between horizontal and vertical transmission in the cultural evolution of language, and the degree to which this interplay may vary for different aspects of language and across different points in time. That is, a key outstanding question pertains to whether we can formulate a theory about the cohesion of transmission of traits vertically and/or horizontally. It is difficult to differentiate the underlying differences between horizontal and vertical transmission, as in one sense there are just traits being transmitted. Thus, the deeper question is how cohesively these traits behave in transmission.

Challenge 7: How Much of Language Consists of Subsystems of Tightly Interlinked Traits?

This problem is about networks of traits in languages (i.e., the systemic view of language): How are traits interlinked within languages, and how lineage specific are these trait linkages? As in biology, where genes interact with each other in complex networks, we can view the various aspects of language as connected in similarly complex networks. Interestingly, in biology these networks tend to be highly structured, with identifiable subsystems of tightly linked genes and various genes constituting "hubs" due to their importance in interacting with other genes (Caldarelli 2007). Moreover, it seems that the resistance of genes to change and horizontal transfer depends on their network properties (Jain et al. 1999; Aris-Brosou 2005), and a similar question arises in language change (Dediu 2011a). These network properties might differ between languages and language families and might influence the trajectory of language change.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

Although there are good reasons for extreme caution in the suggestion that ontogeny repeats phylogeny, it is possible that aspects of ontogeny might be informative as to how the evolution of various aspects of language might be separated. For example, in development, early turn taking provides a framework within which joint attention formats develop. Joint attention is one of the frameworks within which children's "mind reading" and intention reading skills start to manifest themselves before there is any language. Comprehension often precedes production (probably through the use of heuristics). Finally, arriving at the ability to produce all the sounds and structures of one's language is an extremely long-drawn-out process.

Challenge 8: How Does the Study of Language Development and Language Evolution Inform Each Other?

First, in development, different abilities appear at different times and, to some extent, may have different developmental trajectories: turn taking, intention reading, coordinated action, comprehension, simple syntax, fully accurate phonology, complex syntax (see Lieven, this volume). Can this inform the processes involved in the evolution of language? Second, language has been shaped by cultural evolution to be as learnable as possible by children given their cognitive and other limitations (and the way these may change across development). That is, language has been shaped by previous generations of language learners (and users) to fit those biases that children bring to bear on language acquisition (Chater and Christiansen 2010). We may further speculate that gradual changes across development could further result in developmental scaffolding in the cultural evolution of language, in which certain aspects of language are acquired before others, as development unfolds. This may place constraints on the nature and the kind of language systems that can emerge.

Coevolution of Biology, Culture, and Language

Biology and Language

It is undeniable that there has been some coevolution of language and biology in the early phase of language evolution, involving evolution of the vocal tract and possibly the brain. However, it is often assumed that since then biological evolution has become "frozen" relative to language evolution, as if language variation and change works on a "fixed"' biological background (e.g., Chomsky 2010; Hauser et al. 2002). Several reasons suggest, however, that this biological basis is far from "universal" and fixed among individuals (Levinson and Dediu, in this volume). It seems also obvious that language adapts to the brains, the vocal tracts, and the hands of speakers (Christiansen

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

and Chater 2008), but it is also important to recognize that language feeds back on cultural evolution, and thereby potentially influences our biological evolution (Laland et al. 2010).

A number of examples suggest, for example, that differences in vocal tract anatomy might influence language structure, such as the correlation between the Yoruba/Italian vowel systems and the anatomy of the upper vocal tracts of their speakers (Ladefoged 1984). In turn, speech will generate selective pressure on the biological mechanisms used to produce and perceive it, as suggested by the various features of the vocal tract that seem designed for speech (Lieberman 2007; MacNeilage 2008). Thus, the gene–culture coevolution might be very profitably investigated by looking at the evolution of the vocal tract in the human lineage, including modern variation in its physiology and anatomy.

It is thus clear that genetic differences between modern populations might affect language, but it is important to highlight that in most cases these genetic differences exist not because of feedback selective pressures generated by language, but rather as a result of neutral evolutionary processes such as genetic drift and founder effects. In fact, we are a quite genetically uniform species, and the amount of genetic variation present between humans is mostly distributed within populations. Nevertheless, there is genetic variation between populations (Barbujani and Colonna 2010; Novembre et al. 2008), some of which might be due to natural selection (e.g., skin color, resistance to infectious diseases), but the vast majority is probably the result of random sampling.

Are there other aspects of language (e.g., morphology, syntax) that might be influenced by genetic biases? Many aspects of language and speech show moderate to large heritability (Stromswold 2001), which, despite the rather substantial inherent problems of such estimates (e.g., Charney 2012), seem to suggest genetic influences. For example, vocabulary size is somewhat heritable (Stromswold 2001), as is short-term memory buffer size (recently associated with the *ROBO1* gene; Bates et al. 2011); for recent reviews, see Graham and Fisher (2013) and Bishop (2009).

Language is a socially shared system, which is constantly (re)shaped by its users. During the process of social agreement, cultural evolution may introduce accidents which, once emerged, "freeze" and act in their turn as sources of bias for the further evolution of that specific language. These cultural biases compete with genetic predispositions and will in many cases mask them. It is precisely in this sense (i.e., in contrast to cultural biases) that a genetic bias can be defined as "weak" or "strong." Moreover, this tension between culture and biology accounts for the fact that while some properties of language are shared by all languages, other language "universals" (or better termed as "trends") are statistical in nature (Baronchelli et al. 2010).

A model for the emergence of color-naming systems (Puglisi et al. 2008), capable of capturing the statistical properties of the World Color Survey,

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

clarifies this picture (Baronchelli et al. 2010). Whereas a psychophysiological bias (namely, the human "just noticeable difference" bias for hues) acts as a cross-population unifying force in shaping the color categorization of different groups, cultural evolution operates as a source of random yet history-dependent bias at the level of the single populations. It is only through a statistical analysis performed over many populations that the presence of the genetic bias, or equivalently the universal properties shared by the different naming systems, can be revealed (Baronchelli et al. 2010). Interestingly, such biases could be amplified not only by vertical transmission across generations, but also by interactions within generations (horizontal processes), as suggested by Nicaraguan sign language or the emergence of the various village sign languages (Levinson and Dediu, this volume).

When discussing the evolution of cognition, it is often assumed that the growth of specific brain areas happened in response to adaptation to specific cognitive niches (e.g., Pinker 1997; Tooby and Cosmides 2005). However, analyses of allometric data from mammals (Finlay and Darlington 1995) to sharks (Yopak et al. 2010) suggest a scenario more in line with predictions from cultural evolution (Finlay et al. 2001). Specifically, these data suggest that as brains grow bigger, some areas grow proportionally bigger compared to others due to the highly conserved order of neurogenesis following a basic axial structure in development. That is, there is no specific selective pressure required for specific brain areas, only a general pressure for larger brains (though, in principle, selection for a specific brain area could lead to the enlargement of the whole brain). Having a larger brain may have resulted in the availability of more neural hardware which, in turn, could be recruited into brain networks to accomplish specific tasks, without specific adaptation for those tasks. One such example is our ability to read, which is clearly an ability to which we have not been adapted but where brain networks are recruited and emerge during development, specifically, the left occipitotemporal sulcus (Dehaene and Cohen 2007). Similarly, it is possible that other brain networks are recruited during development to support various language functions (Christiansen and Chater 2008)—an evolutionary scenario consistent with recent meta-analyses of the emergence of brain networks as reflected by neuroimaging studies (Anderson 2010).

Challenge 9: What Is the Evidence for Gene–Language Coevolution? Is There Any Other Evidence besides Speech?

Gene–language coevolutionary processes have the potential to broaden our understanding dramatically, but it is currently unclear to what extent these processes actually affect language. There are a few sources of evidence, especially concerning the complex apparatus used to generate speech, where it is hard to find alternative explanations for its apparent design. Other sources of evidence

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

concern larger-scale phenomena where language may have played a major but indirect role in shaping various cultural niches, such as, arguably, in the domestication of plants and animals, which in turn feeds back on our immune and digestive systems. A focused research program aimed at identifying any such putative cases and testing them is needed.

Social Structure and Language

An important aspect of linguistic interaction is the ability to replicate linguistic forms and meanings with a high degree of fidelity. Error correction allows interlocutors to coordinate on the intended meaning of utterances. However, social networks vary considerably in the possibilities for error correction of this kind. For example, more interactive network links, such as conversational interaction (e.g., phone calls, face-to-face meetings), allow for greater error correction, whereas more broadcast sorts of communication (e.g., speeches, written communication, television) allow for fewer possibilities of error correction and hence greater likelihood of modification of the interpretation of the language (Garrod and Anderson 1987; Garrod and Doherty 1994; Fay et al. 2000). These differences in social network structure may influence the nature and tempo of language evolution, especially given the accelerating pace of modern telecommunication systems.

Several distinct mechanisms of propagation of linguistic variants through a social network have been proposed (for further discussion, see Hruschka et al. 2009). The first is social valuation of one linguistic variant over another. This is the classic Labovian model, although Labov (2001), like other sociolinguists, allows for other mechanisms as well. A second mechanism is that differences in frequency of conversational interaction and/or tie strength between speakers may result in the differential replication of the variants used by the more talked-with/stronger-tied speakers (Milroy and Milroy 1985). This mechanism presupposes that changes in use of variants proceeds by some sort of accommodation (Trudgill 1986, 2008). A third mechanism proposed by sociolinguists is an adopter group model (generally inspired by Rogers 1995): a community can be divided into groups based on each group's role in adopting an innovative variant, such that some are leaders, others early adopters, others later adopters, and so on (also influenced by Labov 2001 as well as Milroy and Milroy 1985; recent studies utilizing adopter groups in some detail are Sankoff and Blondeau 2007 as well as Nevalainen et al. 2011).

Empirical studies, however, have been unable to distinguish between the operations of one mechanism over another. Thus, a major open issue is the construction of models able to identify the signatures of different sorts of selection mechanisms, such as those proposed by sociolinguistics. For example, the naming-game model shows that simple horizontal pairwise interactions between peers are able to trigger the emergence of shared linguistic conventions

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

in a population of individuals (Steels 1995; Baronchelli et al. 2006). Thus, more complicated processes might have played a role in the rise of a shared (proto) language, but they cannot be considered as necessary. In the context of the naming game, moreover, the role of the social network of communications has been extensively studied. The time needed to reach a global consensus, along with the individual cognitive burden during the process, turns out to depend dramatically on the properties of the underlying interaction patterns, from fully connected graphs to (spatial) lattices and complex networks (Dall'Asta et al. 2006). Adopting a different perspective, Blythe and Croft (2012) propose distinct mathematical formalizations for social network structure, adopter group models, and social valuation of linguistic variants. The latter is modeled in the same way as fitness in biological evolution, whereas the first two require different mathematical models involving the interaction frequencies and weights of the speakers/agents rather than fitness values on the linguistic variants. Mathematical models such as the one proposed by Blythe and Croft need, however, to be enriched to identify signatures of different types of selection mechanisms.

Another issue is that when multiple mechanisms are in operation, which is highly likely in the case of selection of linguistic variants in speech communities, it is even more difficult to identify the operation of all the mechanisms involved. For example, any selection bias in a small population (speech community) may be swamped by random processes; alternatively, the interaction of multiple processes may lead to significantly different change trajectories compared to each process operating independently. Modeling the change trajectories that result from different selection mechanisms (and their interactions) can provide examples of expected patterns that can be compared to observed data on the trajectories of language changes.

Challenge 10: What Are the Effects of Demography on Language Change and Dispersal?

Demography seems to have fundamental effects on many aspects of cultural evolution; for example, large populations correlate positively with the complexity of technology (Kline and Boyd 2010), but inversely with the complexity of demonstrative systems (Perkins 1995) and language morphology (Lupyan and Dale 2010). What are the generalizations here? Are there principles that would tell us what the largest sustainable speech community would be or, conversely, what is the smallest speech community with long-term viability? For example, generally it seems that a couple of hundred individuals are needed to sustain a distinctive language, but work by Green (2003) demonstrates apparent stability and long-term viability for a speech community of only 70 people in Central Arnhem Land.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

Future Considerations for the Study of Language Evolution

To make substantial new progress, we need new kinds of data, new methods, and new integrative theories that will bind together the many different levels and ontologies for language and its use in communication.

Necessary Data

Comparable Data across Languages Documenting Child Language Development

Dense developmental data are required from different cultures. Theories of language development are largely based on what we know from a very small number of languages. Naturalistic corpus data of children's language development and the language they hear from a wider range of typologically contrasting languages are urgently needed. For instance, take the contrast between learning English, with its fairly rigid syntactic word order and almost total absence of inflectional morphology, and learning most other languages of the world. Corpus data needs to be as dense as possible to be able to determine when children have productive control of a system, rather than repeating rote-learned strings or using low-scope formulae.

Dense Sociolinguistic Data from Different Linguistic Situations

At present we have a large number of studies of sociolinguistic variation from social groups in large-scale, urban, industrial societies. However, next to no variationist sociolinguistic studies have been conducted on small-scale multilingual societies that have marked most of human history. In fact, hardly any variationist sociolinguistic studies have been carried out even on rural social groups in small settlements within large-scale industrial societies. As a result, we know little about within-society linguistic variation and dynamics for the sorts of societies that existed in most of the (pre)history of modern humans.

Data on Variation in Biological Parameters Relevant to Language

It is becoming clearer that variation in diverse aspects of our biology (including vocal tract anatomy, hearing, and associated genes) might affect patterns of linguistic diversity within and across languages (Ladefoged 1984; Butcher 2006), making the construction of a database of such variation an important goal. Such a database will need to contain, for example, information concerning variation in diverse parameters of the vocal tract within and across populations, color perception and naming data, standardized psycholinguistic tasks or brain imaging protocols, and links to databases that contain genetic polymorphisms and fully sequenced genomes.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

Language Documentation, Description, and the Need for Large Corpora

Getting large enough corpora to detect the effects of frequency is a challenge, particularly if we want to get this for the full diversity of the world's languages. Although there has been a big push to build corpora for little-known languages through projects, such as the DoBeS project, that aim to document endangered languages, these rarely contain more than 40–50 hours of data, and usually only a subset of this is transcribed. Psycholinguists know that word frequency has a vital bearing on many aspects of language processing. To get the sort of million-word corpus needed to provide the foundation for processing investigations we would need closer to 1000 hours of data. Much recent work in the psychological modeling of language acquisition and processing has come to rely on dense databases of language consisting of a million words or more. In this context, large data sets are needed to capture the full diversity and idiosyncrasy of language learning and use. Thus, to explore more psycholinguistically motivated models of language evolution, larger databases are needed and they must include crucial use information.

Methods

Computer-Assisted Comparative Historical Linguistics

Comparative historical linguistics is a great method to uncover historical relationships between languages. However, it was conceptualized in the nineteenth century, long before the power of computer-assisted methods was known. We need to reformulate the methods of the "comparative method" so that computer power can profitably be used to reconstruct languages (for an initial step in this direction, see Bouchard-Côté et al. 2013). Basically, the desideratum is to produce not just language trees, but to identify the actual cognate sets, sound correspondences, sound changes, loan words, calques, grammatical borrowing, etc., that are used to infer the trees.

Automated Grammar Extraction, Transcription, Alignment

To transcribe and gloss foreign language text, it is estimated that roughly 100 hours are needed for each hour of recording. Much of this could be semi-automated, together with the temporal alignment of orthography with recordings. Moreover even from small transcribed samples, parts of speech can be automatically extracted by collocation, and using frequency data it should be possible to extract some kind of skeleton grammar. If parallel texts are available, much further automatic grammar extraction becomes feasible. These methods would allow us to work toward the grammatical analysis of all the languages in the world—the exhaustive database we need for understanding the full spectrum of linguistic variation.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

Phylogenetic Modeling

Although considerable progress has been made using phylogenetic models derived from evolutionary biology to model the relatively tree-like evolution of basic vocabulary, computational methods that address more complex histories are likely to be needed to model accurately other less cohesive aspects of language. The new multilocus models in *BEAST, which directly model intraspecies polymorphism and incomplete lineage sorting (Heled and Drummond 2010), might prove a promising place to start. Moreover, recent developments in bioinformatics used to model the evolution of microorganisms that transfer genetic material both vertically and horizontally might be usefully exploited by linguists (e.g., Nelson-Sathi et al. 2011).

Experimental Semiotics

Experimental semiotic studies present living participants with communication challenges in mini-experimental situations, especially in the form of web-based studies with large and structured communities (Galantucci et al. 2012). This may offer a way of testing hypotheses generated by computational studies of language evolution on populations. It may also offer ways of studying the consequences of different kinds of social/communicative networks.

Agent-Based Modeling

There is a strong need for linguists, psychologists, and (agent-based) modelers to work closely together so that complex reality can be matched to modelability, thus permitting the development of useful models to address empirical questions in language change. Much work in agent-based modeling has proceeded in the absence of empirical linguistic data, input from linguists, or psychological considerations regarding learning, memory, and processing. However, it is very important for linguists to specify a priori what linguistic questions they want answered in a model, or to specify what empirical linguistic patterns they would like to see modeled. Given that linguistic reality is very complex, these models are very limited, at least at the present time: that is, there is not a very close match between what models can model and what data linguists have in detail. Moreover, it is also imperative that developmental and cognitive constraints are taken into account to ensure that the models involve psychologically, neurocognitively, physiologically, anatomically, and physically plausible computational constraints. Progress in modeling language change processes can be achieved only through close collaboration between linguists, psychologists, and modelers. Such collaboration requires time for each to understand the other's aims and methods of analysis, as well as to develop a collaborative

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

understanding of the sorts of models and types of empirical questions that can be fruitfully combined to yield linguistically interesting results.

Building Methodological Bridges to Other Disciplines

Given that some of the properties of data concerning language are (partially) shared by data from other domains, it is crucial to build bridges toward these other domains in what concerns methods for representing, visualizing, and analyzing such data. One example could be the spatial nature of some of our data, and useful parallels might be drawn with geostatistics, epidemiology, and Geographic Information System (GIS), or the historical aspects of language and parallels with evolutionary biology. Many more of these types of bridges need to be identified and constructed in the near future.

Theories

Language is central to human social interaction and is, at several levels, a fundamental question for the social and biological sciences. How does language evolve in response to social and biological forces? How is language acquired by each new generation? How is language processed "on-line" in social interactions? These questions have frequently been treated as separate topics, to be addressed more or less independently. As such, studies of the evolution of language typically downplay issues related to language acquisition and processing. Similarly, work on language acquisition tends not to address questions pertaining to the processing and evolution of language, and studies of language processing usually pay little attention to research on language acquisition and evolution. We believe that this tendency is misguided, as there are strong constraints between each domain, allowing each to throw light on the others.

We think that the evolutionary perspective provides a unifying theoretical perspective on language processing, language structure, and language change that is capable of bridging gaps between studies in acquisition, processing, evolution, description, and variation of language. Theory and practice should go hand in hand. What an evolutionary approach to language desperately needs is theories that link sociolinguistic processes to historical patterns (and vice versa). This modeling enterprise should be coupled with team projects that bring together modelers and sociolinguists, psycholinguists and historical linguists, as well as biologists, mathematicians, and many other specialists in their respective fields.

Conclusions

Linguistic systems offer a spectacular parallel to biological evolution, but in the cultural realm. They have extraordinary complexity, and because we cannot

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.

change them to suit ourselves they are largely beyond the ability of individuals to change consciously. Thus they offer us elaborate design without any designer, showing us the "blind watchmaker" of evolutionary processes hard at work. They have lineages of deep antiquity and wide diversity, rivaling some biological systems. Thanks to centuries of human thought about language, we have tools for describing the fundamental units and the processes that combine them. Many significant challenges remain even on the descriptive front, especially in how to find parameters of comparison across lineages. Nevertheless, by applying modern phylogenetic and bioinformatic techniques to current descriptive materials and databases, we are now able to extract deep phylogenies, quantify rates of change, measure degrees of reticulation or horizontal borrowing, or combine these with geographical databases to yield interesting inferences about the spread of languages (Levinson and Gray 2012). We can expect all these data and methods to improve dramatically over the next two decades, allowing many insights into the history and sociology of our species.

From "Cultural Evolution: Society, Technology, Language, and Religion," edited by Peter J. Richerson and Morten H. Christiansen. 2013. Strüngmann Forum Reports, vol. 12, J. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 978-0-262-01975-0.