John Benjamins Publishing Company

The biolinguistics program

Questions and hypotheses

Anna Maria Di Sciullo & Calixto Aguero-Bautista
Université du Québec à Montréal / Université du Québec à Trois-Rivières

The Biolinguistics Program is an emergent interdisciplinary field encompassing natural sciences, neurosciences and the humanities. Its core object of inquiry is human language. The overarching questions it raises are the following: what is language and what is the relation between language and biology. The central hypothesis it brings to the fore is that human language has a biological basis as well as unique traits that make language unique in the biological world. This paper details some of the specific questions and the hypotheses that have been formulated in this field, and it considers recent works on the intersection of language and biology. We start by stating the rationale for Biolinguistics. We then identify the questions and hypotheses raised by this field. Finally, we consider works that aim to bridge the explanatory gap between language and biology while preserving the unique properties of language.

1. The rationale for Biolinguistics

The biolinguistic approach to human language started to crystallize at the epicenter of the cognitive revolution that took place in the second half of the XX century, which, arguably, had a precedent in the great intellectual revolution of the XVII century. The approach emerged out of significant academic discussions among the members of a group of scholars carrying out interdisciplinary research in Cambridge, USA. Important figures of the biolinguistic movement in its early stage include Noam Chomsky, Morris Halle, Eric Lenneberg, and George Miller, among others (Piattelli-Palmarini 1980). This group of scholars sought to provide rational explanations to certain classical questions central to the study of language and mind that, despite beeing considered for centuries, had not been answered satisfactorily. We intend *satisfactory* in this context to mean *explanatory*. That is, we take the position already present at the time of the Port Royal Grammar, and so eloquently advocated much later in generative theories of grammar, that an answer to a linguistic question should not amount to a mere description of the

data but should also provide rational explanations as to why the data should show the particular traits they do. In this regard, the achievement of explanatory power by theories concerned with the fundamental questions of linguistics (or any other science for that matter) becomes a kind of litmus test for measuring and evaluating the competing theories of the various phenomena under scrutiny.

The pursuit of linguistic theory with the goal of explanatory power in mind imposes upon researchers a basic research agenda concerned with the questions of the nature, origin and use of language. The fundamental aspect of these questions is perhaps demonstrated by the fact that the same set of research topics is found on a recurrent basis throughout the history of linguistic thought. In that history, however, although numerous attempts had been made to search for satisfactory answers to those fundamental questions, it was only with the emergence of the biolinguistic perspective that these questions began to be pursued with some considerable depth. It was also with the advent of Biolinguistics that the goal of achieving the power of theoretical explanations in linguistics became a realistic one. Biolinguistics seeks to provide biologically grounded explanations to the properties of language, and especially to those properties that are specific to the human species. To understand the biological basis of language is to understand the innateness of language, a topic right at the crossroads of linguistics and the natural sciences. Perhaps the limited advances of the traditional linguistic theorizing that predated the biolinguistic approach, in terms of its explanatory scope, has much to do with the fact that if one is to provide rational explanations for even the most basic facts of language, the questions in (1) become a necessary part of the linguistic research agenda.

(1)   A: What is the nature and structure of the biological capacity that allows humans to acquire any natural language?
       B: How did the capacity develop in phylogeny?
       C: How does the capacity develop in ontogeny?

But the investigation of these questions before the advent of biolinguistics might have been a premature enterprise, given that the methodological conditions that were necessary for even formulating the questions in a sensible manner were not in place before the 1940s. The required conditions, made possible by a series of key developments in several areas of science (e.g. mathematics, the theory of computation, and biology), appear to have been in place by the 1950s. In particular, the combination of traditional Darwinian evolution with ulterior discoveries in classical and molecular genetics in the so-called *modern evolutionary synthesis* allowed the questions in the traditional research core, alluded to above, to be reinterpreted as the problem of finding explanatory answers for the questions in (1). As Chomsky (2007) puts it, the traditional linguistic concerns got reinterpreted as "the problem of discovering the genetic endowment that underlies the acquisition

and use of language." It is this reinterpretation that is taken to have launched the biolinguistic agenda, a research program that has as its goal the interdisciplinary investigation of the questions in (1). As is often the case in the initial stages of scientific research, the questions in (1) are formulated at a very general level and touch upon issues clearly pertaining to different scientific domains or disciplines (e.g., biology, linguistics, mathematics).

The interdisciplinary investigation of these questions is necessary, although pursuing the same object through different avenues of research and methodology raises the question of whether the results obtained collectively in the different disciplines will ever be unified. This is what is often called the *unification problem*, Jenkins (2000). The path to unification can only come out from the interdisciplinary discussion of the results obtained in the various domains. And the requirement that the independent results of the different interacting disciplines in Biolinguistics be consistent with the fundamental facts of language can go a long way, we believe, in preventing irreducible divergence among such disciplines, see Di Sciullo et al. (2010).

Researchers in the biolinguistic framework have in fact identified a fact of language that is accepted, consensually, as an established fact across the various interacting disciplines. The fact in question is the generalization that human infants, as opposed to the infants of any other species, can acquire any human language without explicit instructions. All that is required for language acquisition to be successful in human infants is that they be exposed to the linguistic data found in the day-to-day interaction among the members of the speech community in which the child grows. By contrast, a pet chimpanzee, for instance (or any other animal for that matter), if exposed to the same linguistic data under the same conditions will not be able to acquire the natural language of the speech community in which the animal grows. A hypothesis consistent with this observation and which can be investigated independently in the domains of linguistics and biology is that there is a biological capacity that is present in humans but absent in chimpanzees, call it the Capacity of Human Biology (C_{HB}), that is responsible for channeling and making possible the acquisition of a natural language on the basis of interaction with experience. At this point we should note that the interesting questions in a biolinguistic agenda (e.g., the questions in (1)) always presuppose the existence of C_{HB}.

We noted above that the questions in (1) are of a very general character. We must say, however, that these questions have become more specific as they have been pursued at the different levels of abstractions imposed by the methods of the various disciplines informing the biolinguistic framework. Thus, the biolinguistic agenda has been extended with newer and sharper questions. For instance, the question of the nature and structure of the biological capacity C_{HB} in (1A) is often decomposed into the questions below.

(2) A. What are the properties of C_{HB}?
     B. What are the necessary components of C_{HB}?
     C. What are the components of C_{HB} that are uniquely human?
     D. Do humans share any of these components with other biological beings?
     E. Are any of these components uniquely adapted to the demands of language?

Similarly, the questions in (1B–C) have been decomposed into the more specific questions in (3).

(3) A. How did C_{HB} evolve?
     B. Was C_{HB} the result of an evolutionary leap?
     C. Was it shaped gradually by natural selection?
     D. How is C_{HB} genetically encoded?
     E. How does C_{HB} grow by interacting with epigenetic and environmental factors (i.e. experience)?

In keeping with the guiding principle in science requiring that the answers to the fundamental questions raised in a given domain be consistent with the obvious facts of the phenomenon under scrutiny, in the given domain, researchers in biolinguistics have sought to find answers and develop hypotheses that are consistent with the most mundane and basic facts of both language and biology. For instance, in answering the questions in (2A–B), biolinguists have started by adopting the hypothesis that C_{HB} is a faculty of language just like the faculty of vision or of hearing. This hypothesis is consistent with a whole array of factual truths in biology, including the fact that human offspring inherit the capacity to acquire language.

Once the consistency of the hypothesis postulating C_{HB} with such biological facts is verified, there are two other mundane facts of language that have been used as guiding points for developing tentative answers for the questions in (2A–B). The first relevant fact is that the mechanism generating linguistic expressions has the property of discrete infinity. What this means is that any sentence can be extended infinitely by adding a discrete linguistic unit to the given sentence. Systems capable of yielding the property of discrete infinity are known to be computational systems. This state of affairs has led to the hypothesis that at least one of the components of the faculty of language is a computational system.

The other relevant fact is that linguistic expressions are externalized by way of sounds or signs and are interpreted by whatever components of the mind interprets the meaning of expressions. The externalization system has been called the sensori-motor (SM) system. The interpretation system is referred to as the conceptual-intentional (CI) system. A plausible hypothesis in Biolinguistics has been that these two components, together with the computational system

mentioned above, constitute the components of the faculty of language. More recently, however, a distinction has been made between the computational system, on the one hand, and the conglomerate of the three components. Hauser, Chomsky and Fitch (2002) call the computational system the faculty of language in a narrow sense (FLN). These authors refer to the combination of the computational system with the SM and CI systems as the faculty of language in a broad sense (FLB). We adopt their terminology here.

With these distinctions in place, the core content of the biolinguistic agenda becomes the set of questions in (4) which we obtain by replacing C_{HB} in (2)–(3) by either the concept FLB or that of FLN or both, depending on what is applicable.

(4)   A.   What are the properties of the FLN/FLB?
      B.   What are the necessary components of the FLB?
      C.   What are the components of the FLB that are uniquely human?
      D.   Do humans share any of the components of the FLB with other biological beings?
      E.   Are any of the components of the FLB uniquely adapted to the demands of language?
      F.   How did the FLN/FLB evolve?
      G.   Was the FLN/FLB the result of an evolutionary leap?
      H.   Was it shaped gradually by natural selection?
      I.   How is the FLN/FLB genetically encoded?
      J.   How does the FLN/FLB grow by interacting with epigenetic and environmental factors (i.e. experience)?

The questions in (4), which span the different areas of research currently being pursued in the biolinguistic agenda, are a testimony to the necessarily multidisciplinary nature of research in Biolinguistics. As we mentioned above, the need of such an interdisciplinary research comes from the fact that many interesting linguistic questions cannot be investigated in depth unless they are reformulated within the various interacting disciplines by abstracting away from those things that are not relevant within the confines of the particular domains. It is difficult to see how a biologist can investigate the evolution of the faculty of language while being agnostic as to the properties of that faculty. This is revealed by the work that the linguist has produced albeit by use of procedures that are very different from those used in the biological domain. Thus, there must be a division of labor among the interacting domains in the field of Biolinguistics. In exploring the nature of the FLB, linguists should provide the linguistically relevant evidence, whereas geneticists, evolutionists, neurologists, etc., should produce the evidence relevant to their specific domains in ways that are consistent with the undeniable facts of language.

It is because of the interdisciplinary and complementary nature of the bio-linguistic agenda, as well as the need for a division of labor among the various scientific domains constituting this multidisciplinary field, that this essay groups current contemporary research in biolinguistics into three related research areas, each dealing with important topics of biolinguistics. The first area mainly addresses the question of the evolution of language. The second area addresses the properties of the FLN and the FLB, as well as their relations from a formal linguistic perspective. Finally, research in the third area is concerned with questions of methodology in Biolinguistics and the search for potential homologues and/or analogues for the different components of the FLB among other species of organisms. This last area advocates a comparative approach to research in biolinguistics and deals, therefore, even if indirectly, with questions pertaining to the unification problem. The following sections outline the scope of these three important research areas.

2.   Evolution of language

The question of the origin of language is as much a question of linguistics as a question of biology. From the biological point of view, perhaps the most salient feature of human language is how isolated it seems to be in the biological world: the fundamental properties of human language seem to be missing in all the other species, including our evolutionarily close primate cousins. This much was recognized since the first classic works on language and has been emphasized by Descartes and Chomsky, respectively working within the cognitive revolution of the XVII century and the so-called second cognitive revolution of the 1950's. Today, given the advances in linguistics and biology, scientific discussion on the origin of language needs to be framed in an evolutionary perspective. This question is a difficult one, however, and although Darwin himself considered it to some extent, in his *Origin of Species* and *Descent of Man*, we must point out that, as noted by Chomsky on several of his lectures on Biolinguistics, Alfred Russel Wallace, the co-founder of the theory of evolution, and who considered the question of the origin of language in greater detail, already concluded that language and other cognitive traits of the human species (e.g., the capacity for mathematics) could not be accounted for by the theory of natural selection in any known possible way. Some modern scholars, however, do try to account for certain properties of language in terms of natural selection. Thus, Pinker and Bloom (1990) lay out the argument that the human capacity for language is an adaptation that has been shaped by natural selection for the purpose of communication. This position, which underlies several works on the evolution of language, came as a response to the mainstream position in linguistics, which holds the view that the relevant facts of language and biology seems to suggest that the former is probably an exaptation rather than an adaptation.

Chomsky's (1988) writes: "Evolutionary theory is informative about many things, but it has little to say, as of now, of questions of this nature [the evolution of language]… in the case of such systems as language or wings it is not easy even to imagine a course of selection that might have given rise to them" (Chomsky 1988: 167). This emergent view of the origins language is at the core of modern Biolinguistics and of the works on the biology of language deriving from the Minimalist Program (Chomsky 1995, and seq.). This research programs seeks to achieve greater explanatory adequacy by getting rid of unnecessary theoretical apparatus (operations, constraints, categories, etc.). As linguistic theory progresses, this methodological reduction is expected in light of the principle of theoretical economy (parsimony), the standard methodological constraint guiding the normal development of scientific progress. By Occam's razor, the classic rendition of this very principle, if two theories are empirically coextensive – that is, if they achieve the same empirical coverage – the theoretically simpler theory is selected by theoretical economy over the theoretically more complex one. The Minimalist Program is consistent with the emergent view of the origin of language. If language emerged recently in history, perhaps about 50–100,000 years ago, and if it remains isolated in the biological world in the face of new evidence, it will be difficult to attribute its emergence to an evolutionary adaptation.

The question then is what part of language if any have homologues among the other living organisms. Several works point to evidence showing that aspects of semantic and general reasoning systems as well as aspects of the sound system are already in place in non-human primates and other species, including songbirds. Thematic agent-patient relations, the ability to count small numbers and to perform elementary arithmetic operations have been observed in monkeys (Hauser 2000; Hauser, MacNeilage & Ware's 1996, a.o.) as well as in pigeons (Rugani et al. 2009, 2011). In contrast, the ability for discrete infinity, or the ability to compute complex vocalic or gestural expressions based on complex syntactic form, such as multiple center embedding, has not been observed elsewhere in the animal kingdom.[1] Assuming the Minimalist architecture of the Language Faculty (5), where the faculty of language in the narrow sense, narrow syntax, (FLN) feeds the semantic and the sensorimotor systems, thus forming the faculty of language in the broad sense (FLB), the origin and the evolution of language can be approached in architectural terms.

(5)   FLN

    SM   CI

---
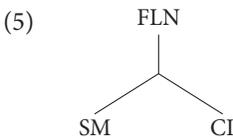
[1]. Quite limited instances are present in the song of Bengalese finches. See work by Michale Fee and Kazuo Okanoya in Bolhuis & Everaert (2013).

For example, Hauser, Chomsky and Fitch (2002) proposed that of the components of the FLB, only the FLN (i.e., narrow syntax) is hypothesized to be unique to the human specie. Berwick (2011), building upon the same point, points out that the uniquely human aspects of language (i.e., those features of language without apparent correlates in the biological world) present a problem for an evolutionary theory based on the assumption that the evolution of language has proceeded on the basis of a continuous, adaptive process. In biology, uniqueness of a feature signals the occurrence of a discontinuous event. Since adaptation works on a continuous evolutionary process, it is difficult to see how such a procedure could shape those aspects of language that are unique to the human specie. Berwick considers how to resolve the discontinuity problem arguing that the "micromutational adaptationist" view adopted in the modern synthesis theory of evolution needs not hold.

The strongest argument for an adaptive theory of language comes from the so-called argument from design. If natural selection is the only procedure that can shape complex derived structures, proponents of the argument would argue, then, that the complexity of language requires the works of that procedure. Borrowing an argument from Hauser, Chomsky, and Fitch, Berwick essentially argues that if the FLN, i.e., the uniquely human aspects of language, consists of a single structure building operation, i.e. the operation Merge in (6), with many cascading effects, then the argument from design disappears. From Berwick's perspective, the only thing that needs to be explained is the origin of the single operation merge, which remains as a discontinuous trait that, although not amenable to adaptive theory, could be explained by alternative deductive systems of regulatory interactions. As defined in Chomsky (2001) Merge takes two syntactic objects a and b, (a, b) and forms a set consisting of a and b, {a, b}. Merge reapplies to its own output. In (7), we provide a step-by-step derivation of the structure consisting of the objects a, b, c, and d, and in (8) we present the result of the derivation in the form a binary branching oriented graph. The formal properties of Merge do not follow from an adaptive theory of the origin of language. They do find an explanation in a constrained deductive system where syntactic objects are combined on the basis of conceptual necessity and elegance to derive the discrete infinity of language.

(6)   Merge (a, b): {a, b}

(7)   Merge (c, {a, b}): { c{a, b}}
      Merge (d, { c{a, b}}): { d { c{a, b}}}

(8)
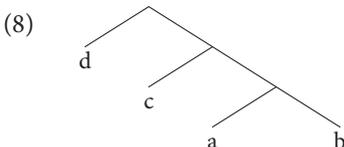
The operation Merge is binary and recursive. That is, it applies to two objects and derives a set formed by the two primary objects, without altering their form. By definition, a binary operation cannot apply to a number of objects n, if n is greater than two. It follows then that Merge may not apply to three objects at once, although it could apply in order to merge two of the objects first, and then apply again to merge the remaining object to the complex object derived by the application of the operation to the first two objects. The new object that is created inherits its main properties from one of the two primary objects. Binary merger can apply to its own output, thus combining previously derived structures, or part thereof, viz., roots or dependents, mother or sister nodes, to other objects. Recursive Merge derives hierarchical structures, the structural properties of which are the main ingredients of linguistic phenomena.

Defined as such, Merge finds no equivalent in biology. An example that comes to mind is the process of cell division in morphogenesis. Cell movement and division is recursive. However, the cell division operation, although recursive, cannot be equated with Merge. For one thing, Merge applies to two objects and yields one (a derived object). Cell division, on the other hand, is a unary operation that applies to one object and yields two. One may wonder if cell division could not be conceived as the homologue of a mirror image of the operation Merge, we might call it Branch, starting with a sentential node as the relevant syntactic object, and then proceeding to branch or split that node into two. Subsequent application Branch to its own output will mimic the recursive property of both Merge and cell division.[2] Like cell division, such a branching operation would be unary and would output two objects from the single one in its domain, but there would still be differences between such an operation and cell division. Daughter nodes, whether derived by Merge or by Brach, are distinct from mother nodes and are actually a part of them, but there is no clear sense in which a new cell could be considered to be a part of its mother cell and different from it. In other words, the structure created by Merge in human language is cumulative, but this is not the case in cell division, and this is probably because such notions as roots and dependents, mother and sister nodes are irrelevant in morphogenesis. This is also the case, needless to say, for more complex relations, such as sister containment, which is central in linguistic agreement and movement phenomena. Moreover,

---

2. Richards (2002) argues that by adopting the operation he calls *sinking*, which is identical to the operation we call Branch here, it is possible to generate syntactic structure in a top-down fashion that besides being recursive like Merge, can help syntactic theory get rid of many conflicts in its set of tests for syntactic constituencies. What is relevant for the present purpose is that *sinking* would be easier to conceive as a homologue of the cell-division operation, although important differences would remain as discussed in the text above.

Merge is a binary set that is of the same category as one of the two merged elements. This tells it even more apart from cell division.
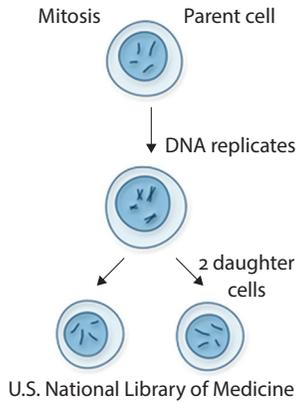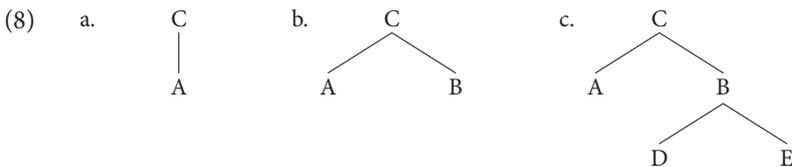

Figure 1. Cell division

As mentioned before, if the Language Faculty consists of only the operation Merge, as proposed by Hauser et al. (2002), the argument for and adaptation theory of its origin loses ground unless it can be shown that the operation Merge itself is complex, and hence derived from more primitive stages. It is, however, difficult to find evidence that Merge must have evolved from a more primitive stage, for example, from a stage where only the dominance relation would be generated, (8a), to a state where only the sisterhood relation would be generated, (8b), to a latter stage where the sister-containment, (9c), would be generated. In fact there is no evidence that Merge would have adapted as a response to selective pressures in a continuous evolutionary process.[3]

(8)   a.   C   b.   C   c.   C
                | / \\   / \\
                A   A   B   A   B
                                                            / \\
                                                           D   E

---

3.   Hauser et al. (2014) discuss four approaches to the evolution of language: comparative animal behavior, paleontology and archeology, molecular biology and mathematical modeling. The paper considers, in each case, that the evidence brought forward is inconclusive and irrelevant. It concludes that little progress has been achieved in that field and the evolution of language is still a mystery.
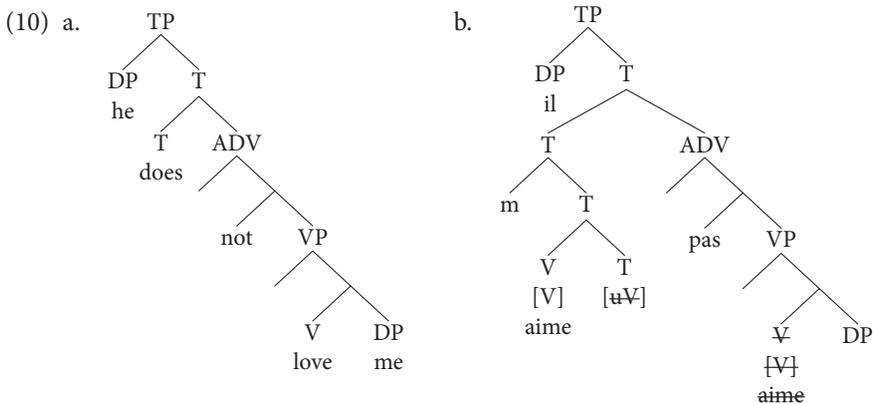
Research in the interdisciplinary field of Biolinguistics can benefit a great deal from the search of homologues of the different components of the FLB in other living organisms in the way just sketched above, and by maintaining researchers in each of the interacting disciplines abreast of the latest findings in each of the fields, with an eye for finding inspiration for the application of such novel findings to the solutions of traditional and emergent problems. As pointed out by several scholars, solutions to such persistent problems might lie within the data uncovered by collaborative research. This point has been emphasized by some of the leading researchers in the field. Thus, Berwick and Chomsky (2011), consider how research can be informed by development in evo-devo biology as well as the framework provided by the Minimalist Program, arguing that if human language is driven by a single recursive, structure-building operation, a conclusion that seems supported by the available evidence, then it is possible to explore the question of how an account of the recent and saltational emergence of the FLN profits from an examination of the ongoing revision of evolutionary explanation in light of new research on evo-devo biology, which highlights the possibility of relatively rapid shifts in an organism's biology given minor variation. Boeckx (2011) makes a similar point, drawing a parallelism between the problem of explaining how language (i.e., the FLN) originated in humans, and the problem of explaining how language growth is possible in ontogeny.

    The search for illumination and inspiration from novel research in the different collaborating fields of Biolinguistics is already bearing fruits. Recent findings in biology and in linguistics reinforce the general approach of D'Arcy Thompson and Alan Turing on the principles that constrain the diversity of organisms in the natural world in parallel ways. Language and living organisms are systems that can similarly be studied at different levels of abstraction. On the one hand, both languages and living organisms can be studied individually (at the level of the species) or collectively (at the level of the phylum), and much can be learned from exchanging information gathered while researching these two analogous domains in such a manner. Perhaps the best example of this comes from consideration of a central question of both linguistics and biology and how the particular question has been approached in both domains. The relevant question is how to best capture the relation between the universal properties of the organisms (languages or living beings) and the apparently great variation found among them. Research within the evo-devo revolution showed around the beginning of the '80s that variations could be restricted greatly and in predictable ways with the work of very small mechanisms that guided the attested variation depending on a very small number of states that such devices could assume. Adoption of such a position in linguistics around the same time resulted in the Principles and Parameters model

(henceforth P&P) (Chomsky 1981, 1986), where variation is the effect of choices or parameters left open in the instantiation of principles of Universal grammar during language growth (Chomsky 1995, et seq.), much in the same way that regulatory mechanisms direct the superficial variations in biology in predictable ways. Although all languages share some universal properties, by virtue of being the results of the same set of universal principles, the P&P approach builds variation in word order in possible differences in the states of parameters associated with the feature system of the different languages, which differ with respect to the choice of the unvalued syntactic features associated with functional categories. Thus, according to the Minimalist Program, language variation is a consequence of feature valuation, which is a consequence of Merge. A minimal difference in the valued or unvalued states of a feature may give rise to language diversity at the micro-parametric level. We can illustrate this, for example, with a concrete example concerning the different position of negation in English and French. Sentential negation precedes the verb in English, while it follows it in French, as shown below.

(9) a.   He doesn't love me.

   b.   Il m' aime pas. (Fr)
        He me loves not
        'He does not love me.'

This variation follows from a minimal difference in the value of the V feature of T. In French, the unvalued V feature of T, [uV], attracts to a higher position than negation, (10b). In contrast, in Modern English, V is valued, and thus it does not attract the verb to a higher position than T, (10a). This parametric feature was however available in Old English, as attested in Shakespearean English, (11).

(10) a. [tree diagram]

TP
├─ DP: he
└─ T
   ├─ T: does
   └─ ADV
      ├─ not
      └─ VP
         ├─ V: love
         └─ DP: me

b. [tree diagram]

TP
├─ DP: il
└─ T
   ├─ T
   │ ├─ m
   │ └─ T
   │   ├─ V [V]: aime
   │   └─ T [uV̶]
   └─ ADV
      ├─ pas
      └─ VP
         ├─ V̶ [V̶] aime̶
         └─ DP

(11)   Some heavy business hath my lord in hand, And I must know it, else he loves me not. (Lady Percy, Act II, Scene III of King Henry IV)

Word order variation, for example the position of the verb with respect to a negative adverb, as well as the position of a nominal complement (DP) with respect to its prepositional (P) head thus follows from a minimal difference in the abstract feature specifications of functional categories, such as T and P. This abstract approach to variation is elegant and does not require an adaptive theory of language variation. Minimalism has been designed to account for such variations, while being entirely consistent with a saltational view of the emergence of language. Moreover, as Di Sciullo (2011, 2012) suggests, there is a homology between the phylogenetic variation observed in language and that observed in the form of bi-partite organisms in evo-devo (Lewontin 2004; Palmer 1996, 2004, 2009), whereby a stage of fluctuating symmetry, where one or the other side of the organism may be prominent, shifts to a stage where only one is. The variation in the position of the verb with respect to negation in Old and in Modern English, as well as the variation of the position of the nominal complement with respect to its prepositional head in the evolution of Indo-European language, and the existence of intermediate fluctuating stages can be seen as being subject to the same symmetry breaking natural law (see also Li & Bowerman (2010) for the role of symmetry and symmetry breaking in biology). Thus, what emerges is a set of principles that constrain the diversity of language and other biological organisms.

The saltational emergence of the FLN contrasts with the gradualist, adaptationist approach to the evolution of syntax. In the adaptationist approach, assumed for example in Bickerton (1990), the evolution of language follows a linear path: the pre-syntactic (one-word) stage precedes the proto-syntax (two-word) stage and this, in turn, precedes the stage called modern syntax. The proto-language, in this conception of the evolution of syntax in ontogeny, is an intermediate step in language development, possibly associated with the two-word phase. However, the notion of "proto-language" is unclear, and different views are available in the literature. According to Jackendoff (2011) "A protolanguage has phonology, but it has little or no constituent structure, no recursion, no subordination, and no functional categories. […] Progovac (2006, 2007) explores this position further, arguing that proto-grammar survives inside and underneath full modern grammars." (ibid, pg. 614–615). Progovac (2015) pursues an internal reconstruction of the stages of grammar based on 'living fossils', such as exocentric VN compounds drawn from English, e.g. *dare-devil*. She argues that these fossil structures do not just coexist alongside more modern structures, but are in fact built into more complex structures, and are suggestive of a gradualist evolutionary scenario. From a Minimalist perspective however, the hypothesis that there would be a proto-language preceding Language, a proto-Merge preceding Merge, is not a viable one, given the principle of theoretical economy referred to above. In the case at hand, the hypothesis that

language emerged as a result of an evolutionary event and that the Language Faculty consists of the unique operation Merge, is simpler than the one positing the existence of proto-Merge, together with Merge. This second theory uses an extra theoretical device; hence the first theory is preferable in light of theoretical economy. Besides this theoretical argument, there is no convincing empirical evidence in favor of proto-Merge, as the analysis of apparently simple structures, such as VN exocentric compounds in English and in other language already have a complex internal structure, hence such a structure is presumably derived, as shown by Di Sciullo (2013), and further discussed in Nobrega and Miyagawa (2015). Di Sciullo (2013) provided evidence that the internal structure of VN exocentric compounds is asymmetrical. The verb bares inflectional features that are validated in a phrasal domain (CP). The internal structure of these compound is that of a relative clause, where the V is structurally prominent (asymmetrically c-commands) with respect to N nominal complement, in cases such as *dare devil*, and the subject is structurally prominent with respect to the verb in cases such as *cry-baby*. Further evidence from similar structures in the Romance languages, such as *crève-faim* and *crève-la-faim* (Fr)*, morto-di-fame* (It) (dead of hunger, 'down-and-out') show overt phrasal constituents (DP), other exocentric compounds include ADVP, AP and PP adjuncts. These facts bring support in favor of a hierarchical structure and against a flat structure for exocentric compounds. Furthermore, they show that no notion of 'living fossil' of proto-language can be based on VN exocentric compounds. Nobrega and Miyagawa (2015) endorse this phrasal analysis and argue further for the precedence of syntax in the emergence of human language.

Phylogenetic evidence indicates that contrary to what is implicitly assumed in the works on evolution of language, including Bickerton (1990), Jackendoff (2011), as well as Hurford (2014), language does not necessarily evolve from more simple stages to more complex ones. This can be seen, for example, by focusing on the phylogeny of a syntactic constituent such as the prepositional phrase (PP). Di Sciullo et al. (2013) provide extensive evidence from the phylogeny of several Indo European languages, showing that while complexity may arise in the structure of PPs, for example by the emergence of postpositions, adpositions or circumpositions, in addition to prepositions, such complexity is normally reduced in the evolution of a language. This is also true of the type of linguistic complexity introduced by language acquisition and languages in contact. We illustrate this below for Italian, similar facts are observed in English and other languages. Thus, while Latin is strongly prepositional, the comitative preposition (cum, con, co) generally precedes its complement, but may also follow it. In Old Italian (13th and 14th centuries) a reduplicated form of the

comitative P may also be found in the prepositional phrase. Modern Italian however, is prepositional:

>Old Italian (13th, 14th c)

(12) a. …. e per li compagnoni che **teco** fuggiro, per li dei…

<div align="right">(Brunetto, Rettorica)</div>

'and for the friends who escaped **with you**, for the gods…'

   b. E altre donne, che si fuoro accorte di me per quella che **meco** piangia, fecer lei partir via…   (Dante, Vita Nuova)
'And her beauty is so virtuous that there is no envy from the others, she made them go **with her**, with [lit. dressed of] kindness, love and faith.'

   c. neiente de lo mondo ; **con te** le tue, parole voria **conte** avere…

<div align="right">(Rinuccino, Sonetti)</div>

'And close by came a cavalier against her, very large, deformed and terrible to the sight, well armed with black weapons, on a very large horse; and he had **with him** so many people who were covering the entire field.'

   d. Ballata, i' voi che tu ritrovi Amore, e **con lui** vade a madonna davante, sì che la scusa mia, la qual tu   cante, ragioni poi **con lei** lo mio segnore.   (Dante, Vita Nuova)
'Ballata, I want you to find love again, and **with him** go to see the madonna in front, so that my excuse, which you sing, you reason **with her** my lord'

   e. Gli altri tenea in pregione, e costui di fuori, **con seco**, e vestialo nobilemente   (Anonimo, Novellino)
'He was keeping the others in prison and this one outside **with him** dressed like a noble man.'

   f. … Amor non venga sempre ragionando **con meco**, et io **collui**.

<div align="right">(Petrach)</div>

love not comes always talk with me=with and I with him.
'love doesn't always come talk with me, and I with him'

   g. Non ti dar malinconia, figliuola, no, ché egli si fa bene anche qua; Neerbale ne servirà bene **con esso teco** Domenedio

<div align="right">(Boccaccio, Decamerone)</div>

'Don't be sad daughter, no, because he will do well here as well; Neerbale will do well **with you** [lit. with FOCALIZER you] Domenedio.'

In Latin as well as in Old Italian *con me* and *meco* are derived, given the displacements for feature valuation of the [uD] feature of P. The P-shell includes two P heads, one of which is not spelled out, (13a,b). However, both heads can be spelled out at a given point of the historical development, giving rise to *con meco* and *con*

esso meco.[4] Through the diachronic changes the only derivation that survived is the one requiring the fewer steps. Only one possibility remains in Modern Italian: *con me*, (14a).[5]

(13)   a.   b.

(14)
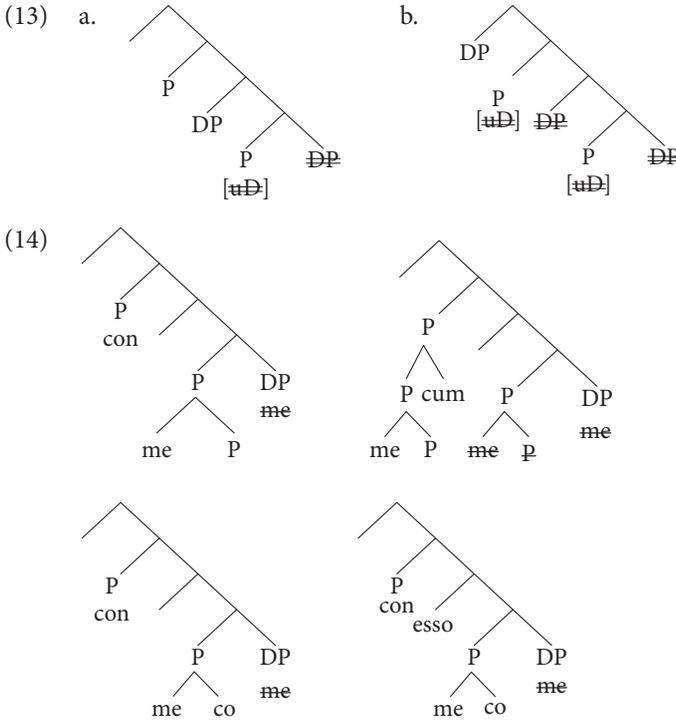
Di Sciullo et al. (2013) provides cross-linguistic evidence based on English and Estonian that the oscillation of a complement with respect to its prepositional head

---

4.   Modern Spanish have similar forms like *conmigo* 'with me', *contigo* 'with you' and *consigo* 'with him/herself', with two copies of the same preposition spelled out at both side of the pronominal element, and voicing of the initial velar stop on the rightmost copy of the preposition. This is also the case in Brazilian Portuguese, as well as in other languages. The Directional Asymmetry Principle (Di Sciullo 2011) predicts that complexity followed by its reduction will take place in language diachrony. This developmental principle, does not predict exactly when this reduction will take place.

5.   Notice that if Kayne (1994, 2011) is correct in assuming that there is no head-parameter, a position consistent with the current minimalist assumption that parameters are restricted to certain inflectional properties of lexical items, then it follows that of the three types of prepositional order given above; that is, prepositions, postpositions, and circumposition, the modern Italian head initial *con me* is simpler than the other variants discussed above. This is because, assuming with Kayne that phrases are universally head initial, *con me* can be put

is Case dependent. The facts indicate that cross-linguistically the grammatical principles have precedence over principles external to the Language Faculty, as argued independently in Di Sciullo and Aguero (2008) on the basis of the difference between Binding and Coreference to account for the so called 'delay of Condition B effect' in first language development, see below pp. 19–20.

In a diachronic perspective, once internal factors allowing for a certain structure vanish, external forces to the Language Faculty will drive diachronic development. The fluctuation between the pre and post-position of the complement with respect to its prepositional head is reminiscent of the stage of fluctuating asymmetry that has been observed in evolutionary development (evo-devo) of bipartite organisms (Palmer 2004, Levin and Palmer 2007, Lewontin 2000). The fluctuating asymmetry stage is followed by a stage of directional asymmetry, where one side of a bipartite organism is prominent. Di Sciullo (2011) shows that the Directional Asymmetry Principle (DAP), according to which language development is symmetry breaking, will reduce the complexity brought about in an instable grammatical system, where two valued of a same feature are available, as represented in (15) for the valued, [D], and the unvalued D, [uD], feature of P. All things being equal, it follows that P – DP will become the only available option under the DAP for Modern Italian or Modern English.

(15)   P
         /\
      [P]   [P]
      [D]   [uD]
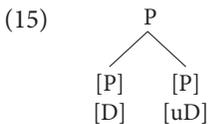
Since the early days of generative grammar, language variation, including diachronic variation, has been linked to language acquisition (Chomsky 1981; Lightfoot, 1979, 1982, 1991; Robert & Roussou 2003, Roberts 2007, 2011). An interesting question from this perspective is whether there is a pattern along the line of the DAP that is observed in language acquisition. We will leave this question for further research.

Since the very inception of generative grammar, a guiding heuristic has been to view language development, in its essential properties, as a process resembling more the growth of organs in living organisms than the process of inductive

---

together by External Merge. The other variants, however, would require both External Merge and Internal Merge, being therefore more complex. Languages show however fluctuation with respect to the pre- and postpositional structures, as it is the case for Russian, Chinese, and Pashto. Moreover, most languages tend to eliminate the fluctuation in favor of the simplest derivation, as discussed in Di Sciullo (2011), Di Sciullo & Somesfalean (2013, 2015) and Di Sciullo et al. (2013).

learning on the basis of experience. This view has required the hypothesis that the essential principles of language development (growth) are given to the human species as part of our genetic endowment. Organ growth, generally, requires the interplay of two factors: the genetic program or set of specifications directing the way in which development of the relevant organ is to proceed, and environmental factors, determining the unfolding of the program. This much has been recognized since the beginning of the biolinguistic framework (Chomsky 1968, 2005, 2011, Lenneberg 1967).

Three facts provide a strong argument for the genetic specification of human language. The first fact is that it is specific to the human species, and if the infants of humans and other intelligent creatures (e.g., pets) are exposed to the same linguistic experience, only the human infant will ultimately develop human language, despite the fact that the experience factor is kept constant. The second fact is the rapidity with which human language develops. This fact actually allows us to construct a mathematical argument for the genetic basis of language growth. Our capacity for understanding the sentences of our native language is mathematically astronomical and children seem to have this capacity in place by age three, as frequently pointed out when lecturing on the subject. What this means is that given the mathematical size of the set of linguistic expressions, we simply have no time for learning the things about such expressions that we know at a very early age. Pinker (1994) illustrates the issue by pointing out that any human capable of dealing with a twenty-word sentence, is capable of dealing with 10^{20} variations of such sentences. This number is huge (a one followed by twenty zeros or a hundred million trillions) and Pinker correctly points out that if one learns such sentences at a rate of five seconds per sentence, one would need to have an infancy of a hundred trillion years in order to know what we know about such variations. The third fact that argues for the genetic specification of human language is the fact that we know of certain linguistic properties that are not present in the linguistic input. This is known in the linguistic literature as the poverty of the stimulus argument, Chomsky (1986), Piattelli-Palmarini & Berwick (2013), we refer the reader to the extensive literature on the topic for detailed discussion on the relevant issues.

Reexamination of the previous facts as to whether they provide an argument for the biological and/or genetic foundation of language has essentially reaffirmed the generative position. For instance, the species-specific property of human language has been acknowledged by Gallistel (1990) who noted that nonhuman mammals with good statistical learning and computational capacities nevertheless do not develop language.

The mathematical argument discussed above in support of a genetic specification of human language is at times ignored on the basis that language acquisition, although admittedly a rapid process, does not seem to be instantaneous.

The conclusion that language acquisition is not instantaneous, however, is not warranted. It might be the case that there are maturational principles of the kind discussed by Ken Wexler and his collaborators obscuring knowledge of language in childhood. One such principle might be Wexler's *Unique Checking Constraint* (UCC) (Wexler 1998). According to this principle, the linguistic genetic system developing in childhood has the property that more than one checking are not allowed at young ages in the same linguistic environment. In the clausal domain, AGReement and Tense cannot be both checked, because of the UCC, and thus only one is eliminated giving rise to the Optional Infinitive stage. The child's expressions in the relevant domain will become adult-like once the constraint in question becomes irrelevant with maturation.

While language evolution is still a mystery, the biolinguistic program provides a search space for the formulation of questions and hypothesis leading to a further understanding of human language, its emergence and its constrained variation through time and space.

3.   The structure and properties of the FLN/FLB

The question of the evolution of language depends to a great extent on the question of the structure of the linguistic capacity. Minimalist linguistics (e.g. Chomsky 1993, 1995, 2001) recognizes at least three different components of what has been called the faculty of language in a broad sense (FLB): the computational system responsible for recursively combining linguistic expressions, what Hauser et al. (2002) call the FLN; the sensorimotor system (SM), responsible for the externalization of linguistic expressions; and the conceptual intentional system (CI), responsible, among other things, for the interpretation of linguistic expressions. Biolinguistics seeks to investigate the exact properties of these cognitive systems as well as the exact relation among them, and many scholars today are exploring the issues surrounding such question. For example, Larson (2011) explores the question of the relation between the FLN and the FLB. What is the exact relation between these two systems? A working hypothesis has been that the FLN is a component of the FLB together with the SM and CI systems as schematized in (16).

(16)   FLN
              / \   } FLB
          SM   CI
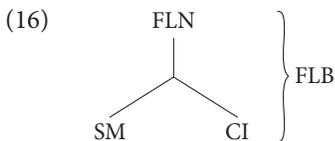
FLN has been taken to be the sole human-specific dimension of the FLB (e.g, Hauser et al. (2002)). Merge is hypothesized to be the core operation of the FLN.

As mentioned above, Merge is a binary and recursive structure-building operation. Two types of Merge have been proposed: External Merge, and Internal Merge, the latter being responsible for carrying out the displacement of syntactic constituents. The computational system or FLN includes an operation Select that makes a onetime selection of a set of items from the lexicon, called a numeration (N). The operation Select can also apply to N, in order to extract an array of lexical items from it and place it in the workspace. Elements in N are parts of the workspace and await further computation. The FLN also contains the operation Agree. Agree drives the checking/valuing of features and generally leads to displacement. The items from the numeration are associated with formal, semantic and phonetic features. Formal feature can be valued or unvalued. Unvalued features must be valued in the syntactic derivation before the expressions they are part of reach the interfaces. Thus, the output of Agree complies with the demands of the Principle of Full Interpretation. According to this principle, only expressions including valued features can be interpreted by the external systems, semantic and sensorimotor. The operations referred to above can informally be defined as follows:[6]

(17)   a.   Merge (Chomsky 1995)
            Target two syntactic objects α and β, form a new object Γ{α, β}, the label LB of Γ(LB(Γ)) = LB(α) or LB(β).

       b.   Merge (α, β): {α, β} Chomsky 2001
            External Merge applies to two separate syntactic objects;
            Internal Merge applies if either of them is part of the other.

(18)   a.   Numeration: the set of lexical items extracted from the lexicon by Select with their original features.
       b.   SELECT: an operation that selects items from the lexicon (i.e. the numeration) and from the numeration (i.e. the lexical arrays) and inserts them into the workspace.
       c.   Workspace: the space where the derivation unfolds and which will eventually contain the output of the recursive application of Merge.
       d.   TRANSFER: operation that ships linguistic expressions at different moments during the derivation to the SM and CI interfaces.

According to Di Sciullo (2005, 2014), morphological Merge applies to a pair of elements in the Numeration whose sets of features are in a proper inclusion

---

6.   See Chomsky (2013, 2015) for the latest development in Minimalism, including the labeling algorithm, which simplifies the definition of Merge as well as it unifies other principles, including the Extended Projection Principle (EPP) and the ECP Empty Category Principle (ECP) in terms of labeling.

relation, (19). This is also the case for syntactic Merge, according to Di Sciullo and Isac (2008), (20).

(19)   Numeration: {compute: [V], -able: [A, uV],   un-: [A, uA], -ity: [N, uA]}

(20)

```
                    N
           ┌────────┴────────┐
           A              -ity
     ┌─────┴─────┐       [uA, N]
   un-           A
 [uA, A]   ┌─────┴─────┐
        compute     -able
          [V]      [uV, A]
```
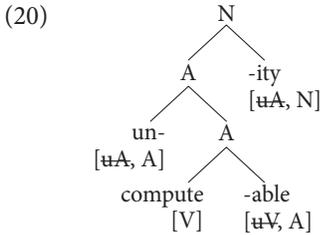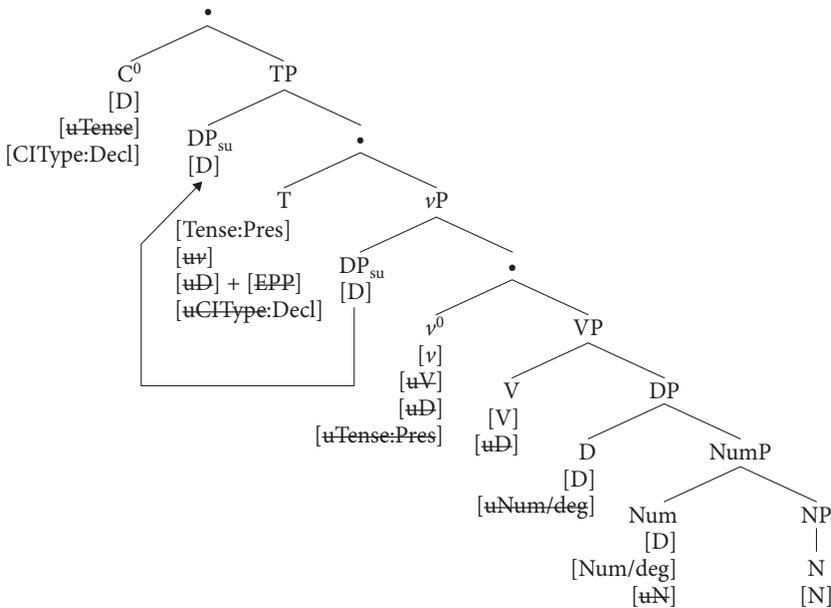
According to Di Sciullo and Isac (2008), syntactic Merge is an operation that applies to a pair of elements in the Numeration whose sets of features are in a proper inclusion relation.

(21)   Numeration: {C, T, {D, Num, N, v, V, D, Num, N}}

(22)

```
                        •
              ┌─────────┴─────────┐
             C⁰                   TP
             [D]          ┌────────┴────────┐
          [uTense]      DP_su              •
         [ClType:Decl]  [D]        ┌────────┴────────┐
                                   T               vP
                              [Tense:Pres]   ┌──────┴──────┐
                               [uv]        DP_su          •
                              [uD] + [EPP]  [D]      ┌─────┴─────┐
                             [uClType:Decl]        v⁰          VP
                                                   [v]      ┌───┴───┐
                                                  [uV]      V      DP
                                                  [uD]     [V]   ┌──┴──┐
                                               [uTense:Pres] [uD] D    NumP
                                                               [D]  ┌──┴──┐
                                                          [uNum/deg] Num   NP
                                                                     [D]    │
                                                                  [Num/deg] N
                                                                    [uN]   [N]
```

In both cases, the criterion for deciding the order in which items in the Numeration must be Merged is the proper inclusion relation: the set of features of the merged item must stand in a proper inclusion relation with the set of features of the object derived in the workspace. Asymmetry is deeply-rooted in syntactic composition.

Within the foundational assumptions of the Minimalist Program, the hypothesis that the FLN is an optimal solution to legibility conditions, imposed by the SM and CI systems, has been a productive one. From a methodological point of view, the search for interface conditions imposing demands on the FLN is a programmatic objective and guiding heuristic of the Minimalist Program and such a search has in fact intensified recently. Larson (2011) suggests that a promising place to search for such conditions is provided by the phenomenon of intentionality as it is represented in syntax. More precisely, Larson argues that the semantic property of intentionality is strongly correlated with the syntactic environment of clausal complementation, a fact that can be concealed by the surface properties of linguistic expressions. Larson further argues that mastery of intentionality appears to correlate with mastery of clausal complementation, in language acquisition, and with the development of a child's theory of mind. Larson suggests that it is plausible that the correlation between intentionality and clausal complementation reflects an interface constraint requiring that the CI system inputs the propositional units sent by the FNL only when these are presented in an appropriate format. Larson observes that the results of his research suggests a view of the notion of a phase, that is a unit of computation and interpretation, see below p. 26, that is different from the one assumed in the Minimalist Program in that it "adverts" to notions like memory and processing load. As he puts it, "[it] can be seen as the point where the Language Faculty computes propositions for the psychological faculty."

Besides the search for conditions imposed by the external systems on the structure of the FLN, contemporary minimalist research also seeks to independently investigate the very nature of such a cognitive system. Lasnik (2011), for instance, reconsiders the question of the generative power of the syntactic system associated with the FLN. To generate such common linguistic expressions as those involving agreement among certain syntactic constituents, at least the power of context free procedures is needed over the less powerful finite state Markov model (an argument made by Chomsky 1957). This is because context free grammars introduce abstract structure that is not visible on the surface or linearized linguistic expressions but play a role in syntactic computations. Since some grammatical operations like the phenomenon of agreement operate on such abstract structures, it follows that such grammatical operations cannot be generated by Markovian models. Lasnik, however, points out that there are areas of syntax that appear to involve a flattened structure. Such structures were used as motivation for the move into transformational grammar, but Lasnik expresses uncertainty as to whether transformations can solve the problem of coordination. He wonders if we need to retain the lower power of Markov procedures for such cases. Arguing that Markovian vs. non-Markovian properties have also been discussed with respect to transformational derivations,

Lasnik notices that there have been early and recent arguments for globality in derivations and discusses the implications of some such cases.

In addition to the search for conditions and/or architectural constraints determining the relation between the FLN and the SM interface, on the one hand, and that between FLN and CI interface, on the other, Biolinguistics also assumes the existence of language independent principles that apply to natural phenomena generally, including language. These are the principles that Chomsky (2005) calls the third factor principles. General principles of economy and efficient computation fall within this category. The assumption that the FLN only consists of the sole operation Merge, leaves researchers in Biolinguistics with a heavy task: to show that the role of the many principles attributed to UG in the previous stages of the P&P approach can be accounted for without the given principles. Within the Minimalist Program, some researchers have started to carry out such a task by reanalyzing phenomena previously treated in terms of principles of UG, and their applicability or inapplicability, as phenomena resulting from restrictions imposed by third factor principles. As an example of this practice, consider the so-called Delay of Principle B Effect discussed by us in earlier work (Disciullo & Agüero-Bautista 2008). A number of studies show that children from various languages around age 5 seem to violate Principle B, when the antecedent of the pronoun is a name, but not when the antecedent is a quantifier (Chien & Wexler 1990; Grodzinsky & Reinhart 1993, for English; Koster 1993; Philip & Coopmans 1996, for Dutch; Avrutin & Wexler 1992 for Russian). These findings are at first sight unexpected if Principle B, (23), where governing category refers to the minimal propositional or nominal categry including the pronoun, is one of the principles of UG, something that seems to be the case given the universality of this principle in adult speech, (24).

(23)   Principle B: A pronoun must be free in its governing category.

<div align="right">(Chomsky, 1981)</div>

(24)   a.   John$_1$ likes him$_{*1/2}$
         b.   John$_1$ said that Peter likes him$_{1/2}$

According to the Standard Analysis (Grodzinsky & Reinhart (1993), there are two strategies of anaphora resolution: Binding and Coreference (see (25)). Principle B is about binding, not about Coreference. There's an interface principle (Rule I) that ensures that binding takes precedence over coreference (see (26)).

(25)   Two Strategies of Anaphora Resolution for a sentence like (1).
         a.   Binding
               λx (x touches x) (Mama Bear)
         b.   Coreference
               Mama Bear$_1$ touches her$_2$ (where 1 = 2)

(26)   **Rule I**
       NP A cannot corefer with NP B if replacing A with C, C a variable
       A-bound by B, yields an indistinguishable interpretation
                                          (Grodzinsky & Reinhart 1993).

One of the intriguing features of the phenomenon is that it is not universal in all environments, as it is notably missing in languages with clitic pronouns in simple clauses (McKee 1992; Baauw et al. 1997, 1999), as in (27), but found to some extent in ECM-type contexts (Baauw et al. 1997, 1999), as in (28). The right theory of the acquisition of Principle B should therefore account for the cross-linguistic presence and absence of the DPBE.

(27)   Gianni lo asciuga   (It)
       Gianni him-dries off
       'Gianni dries him off.'   (McKee 1992).

(29)   La madre la ve ballar   (Sp)
       The mom her-sees dance
       'The mom sees her dance.'   (Baauw et al. 1997)

The DPBE is a complex phenomenon that seems to be determined by non-linguistic and linguistic factors. The non-linguistic factors include the ability to handle the additional computational complexity implied in the process of comparing alternative structures in order to choose the optimal one, what Collins (1997) calls global economy.

Di Sciullo and Aguero (2008) argue that the DPBE is not due to a lack of knowledge of Principle B, or any other aspect of the binding theory, but rather to the fact that certain Interface principles induce comparison of structures for truth-conditional equivalence, such as Fox's (2000) Scope Economy principle, (29).

(29)   **Scope economy**
       The output of a scope-shifting operation must be semantically different
       from its input.

Both adults and children know Scope Economy in addition to Principle B, but kids in languages with clitics get lost, just like their Germanic counterparts, when having to compare two structures for equivalence. In such cases, kids in languages with clitics also take a guess in the process of interpreting an antecedent-pronoun/variable dependency, with the result that they also perform at chance level.

4.   A comparative methodology and unification of results

The biolinguistic program is the study of language as a biological object. This section is concerned with questions of methodology in Biolinguistics. A comparative

approach that searches for potential homologues or analogues of the components of the Language Faculty in other organisms is needed. Understanding the multidisciplinary nature that such a comparative approach presupposes also lead to important issues that are central to the goal of obtaining convergent (unified) results. A number of researchers have in fact emphasized this point. Thus, Piattelli-Palmarini and Uriagereka (2011) highlight the importance of searching for convergent results in one important area of both language and biology: the genetics of language. They essentially argue that, to be plausible, results in the genetics of language should be compatible with sound evidence in the domains of both linguistics and genetics. To illustrate the problem they discuss the case of the FOXP2 gene, which has recently been found to play a role in a very specific language deficit in a population of subjects they refer to as the AKEFIs. Subjects in the affected population have problems producing and understanding linguistics expressions involving tense, number, and gender agreement. This has at times been referred to "feature blindness," (e.g., Gopnik 1990). The mastery of these different areas of grammatical agreement is fundamental for the normal development of a language in the individual. The genetic nature of the condition is suggested by the fact that the syndrome is caused by a mutation in one of the copies of the FOXP2 gene. But explaining how exactly the FOXP2 gene is responsible for the language deficit has proven to be a thorny issue. Piattelli-Palmarini and Uriagereka point out that some of the analyses proposed to explain the connection between FOXP2 and the language deficit with AKEFIs assume an implausible conception of language, which essentially equates language to the sensorimotor system. As we saw above, the SM system is just one of the components of the FLB. The FOXP2 gene is known to regulate many other genes that in turn play a role in the development of brain tissues in different brains loci. The authors warn, however, against an analysis that purports to find a neat mapping between genes and brain loci on the basis that no area of language seems to be plausibly circumscribed to one single brain locus. In looking for an alternative explanation that is more consistent with the linguistic evidence, Piattelli-Palmarini and Uriagereka point out to the fact that the FOXP2 gene has a counterpart in birds, the Foxp2 gene. Drawing from conclusions in the role of this gene in the acquisition of bird songs found in the relevant literature, these authors suggest that the language deficit in AKEFIs might result from damage to an area of the brain implementing the human language parser caused by the specific mutation in the FOXP2 gene.

In a similar vein, Jenkins (2011) argues for a comparative method under the assumption that homologues to natural language could be found in other organisms and domains. For Jenkins, the study of the biology of language, i.e. *Biolinguistics*, encompasses the study of knowledge of language, its development in the child and its evolution in the species. Each of these areas can be studied while abstracting away from underlying physical, neural and genetic mechanisms. For

example, one can study the Language Faculty by studying properties of language such as word order and distribution of pronouns and anaphors. The development of language can be investigated by looking for both universal principles and language-specific variation across many languages. Language evolution, its use, and development, can be studied by mathematical models simulating language change in time. Jenkins emphasizes that the biolinguistic program hopes to relate the properties of the Language Faculty discovered in linguistics (and in particular to the research areas outlined above) to physical mechanisms at the level of language micro-circuits of the brain and of language genetics. In recent years, there have been a large number of studies of specific genes which have been associated with language. The case of the FOXP2 gene mentioned above is one example, but there are other similar comparative studies where the subjects compared are humans, non-human primates, mice and birds.

In addition to the comparison of research across species, much can be learned from comparing different brain or cognitive areas in the same or different species. For instance, the development of language is often compared with the development of vision, and the existence of critical periods has been investigated in both domains. Although the molecular basis for the "critical period" for language learning has not been found, genes involved in the critical period for vision have been identified. From the perspective of a comparative approach, there is hope that further understanding of the development of vision can be used to illuminate language development and vice versa. In general, the comparison of brain areas within and across species can only reward us with the wealth of new data and evidence needed for understanding the very nature of such complex problems.

The search for possible homologues to the different components of the FLB, among the other species, has led to a burgeoning area of comparative animal work. Fitch and Hauser (2004), for instance report that cotton-top tamarins are able to learn an artificial language, through a long process of training. The type of artificial language they have in mind can be generated by a finite state machine. Cotton-top tamarins, however, cannot learn a language whose grammar has the generative capacities of phrase structure grammar. This does not entail that the human capacity for language originates in finite state grammars. That humans outperform cotton-top tamarins (and all other creatures for that matter) in our command of such generative devices like phrase structure grammar is not a mystery. This is expected in light of experimental results like the one reported in Musso et al. (2003), suggesting that Broca's region is "[…] specialized for the acquisition and processing of hierarchical (rather than linear) structures, which represent the common character of every known grammar." (ibid, pg. 778). See also Bahlmann et al., 2008.

Similarly, Berwick et al. (2012) suggest that the structure of bird song could be derived by concatenation, and here again there is a gap between bird song and

human language, as only in the case of human language does hierarchical syntax ensure the association of form with meaning. Berwick et al. point out that the capability for auditory–vocal learning is not shared with our closest relatives, the apes, but is present in such remotely related groups as songbirds and marine mammals. While there are convergent evolutions of the capacity for auditory–vocal learning, and possibly for structuring of external vocalizations, there are significant limitations arising in the ability to compose smaller forms such as words into phrasal constituents. One sticking aspect of comparing the syntax or bird songs to that of human language is the pervasive role of asymmetric relations in the latter (see Kayne 1994; Moro 2000; Di Sciullo 2005). Such relations are not found in bird songs. For example, in English, verbs form syntactic units with their complements, but not with their subjects. This suggests that syntactic units are put together in a highly cyclic fashion, requiring that certain syntactic objects be built first in the workspace, before others constituents can be added to the growing syntactic constituent (Chomsky 1995, 2001; Hornstein & Uriagereka 2002; Di Sciullo & Isac 2008). Neither such asymmetries nor the cyclic fashion in which syntactic objects are constructed has been found in bird songs. A similar point can be made with the fact that complements can be displaced in embedded context contrary to adjuncts (Huang 1982; Rizzi 1990; Chomsky 1995, a.o.). This points toward the existence of natural language asymmetries arising as a consequence of the inner workings of Internal Merge and the interaction of this operation with the different syntactic cycles. Again, such properties of form have not been observed in bird songs, or the vocalizations of marine mammals and apes. More generally, the structure dependent character of syntactic phenomena (e.g. wh-extraction phenomena in questions and exclamation formation), determining the exact context in which syntactic operations apply or fail to do so, although they have been acknowledged as a common property of language since the very beginning of Generative Grammar (Chomsky 1965, 2013), does not seem to have analogues in the biological world.

The research strategy of searching for possible homologues of the different components of FLB is expected to change our original views of such components, as new evidence is considered. This is already happening, for instance, with respect to our conception of the operation Merge. Although Hauser et al. (2002) takes the position that only Merge seems to be specific to the human species, evidence reviewed in several works seems to indicate that Merge is not human specific. Thus, Byne and Russon (1998) arrives at that conclusion studying the process of food preparation with mountain Gorillas, while McGonigle et al. (2003), Seyfarth et al. (2005) and Schino et al. (2006) do so while respectively studying the capuchin monkeys' ordering of objects, baboons knowledge of their companions, and Japanese macaques knowledge of their companions. But even if homologues of Merge can be argued to exist in other domains among the various species of the

primates, one can still argue that the way this operation is used by the FLN is uniquely human. As discussed above, natural language expressions can be put together either by External Merge or by Internal Merge. It is the combination of these two types of Merge that is responsible for the unbounded character of linguistic expressions, but nothing like Internal Merge has ever been reported in the literature on primatology or ethology, which rules out the possibility of homologues of the way Merge is used in humans among the living organisms of those species. Internal Merge yields Operator-variable structures, Opx (…x…), and such structures are likely to be human-specific. Quantificational operator-variable structures are necessary in theoretical languages and determine the expressive power of linguistic expressions, making possible the generation of terms of a very symbolic (non-referential) nature. The reasons why Internal Merge seems unavailable to other species have already been considered. Thus, Uriagereka (2008) argues that, as a context-sensitive operation, Internal Merge places greater demands on working memory than does External Merge alone. The probe-goal search, required by Internal Merge, involves scanning the derivational record to find the object to be merged. External Merge does not require a scan of the derivational history. So, less developed working memory in the other primitive species might suffice to explain their using Merge, but not Internal Merge (Coolidge & Wynn 2005).[7] Accounting for the biological isolation of Internal Merge will hopefully lead to an account of the uniquely human systems of open-ended expressions (e.g., linguistic expressions, number systems). A system based on merging lexical items one at a time, and where the operation Merge can apply to its own output, is a system of discrete infinity. Number systems are also systems of discrete infinity. One could possibly argue that the operations responsible for the discrete infinity property of number systems are derivable from Merge, hence our understanding of Internal Merge, besides illuminating the open-endedness and symbolic character of linguistic expressions, may also be expected to shed some light on our understanding of such similar systems as music and mathematics, while generally explaining the similar isolation of these systems in the biological domain. Symbolic reasoning, the ability to think beyond the here and now, is a by-product of our uniquely human, not evolved piecemeal and gradually as an adaptation, cognitive capacity, a capacity best put in display in our handling of unbounded expressions. The

---

7.   Research in this area is just beginning, so the issues are far from being settled. Important questions arise at each turn. In the present case, an interesting question is the relation between memory and working memory. Some animals, e.g. elephants, are known to have a big memory. Can we find evidence of items placed in large working memories when a computational task is being carried out among the other species? If so then we can proceed to investigate the question of whether or why such species have not developed Internal Merge, and whether possession of such an operation is independent of the size of the working memory.

ability for the human mind to compute complex linguistic expressions might, therefore, be a consequence of the great leap from our ability to deal with finite and continuous systems, such as the gesture system, to our capacity for handling systems of discrete infinity, such as language, mathematics and music.

The closest homologue to language is found among the insects, despite the fact that many of the brain components that interact with the faculty of language are widely shared among the species (Fitch 2011). Recognizing this fact, as well as the uniquely human origin of some of the capacities separating Homo sapiens from other living beings, Fitch (2011) points out that some of the novel capacities may depend on different underlying mechanisms that have a separate evolutionary history. Addressing how the mechanisms in question evolved, Fitch argues, requires a comparative approach that goes beyond the study of non-human primates to include virtually any living organism. "If we want to understand which aspects of a trait like bipedalism or vocal learning are incidental, versus either phylogenetically or developmentally necessary, our best source of empirical data will be from multiple species that have evolved that trait independently of one another … Deep homology exists when the developmental mechanisms responsible for generating a trait are shared by common descent, even though the phenotypic trait itself was not present in the common ancestor (Shubin, Tabin & Carroll 1997; Hall 2003). For example, the wings of flies and those of birds are not homologous in any traditional sense (the common ancestor of birds and flies did not have wings). Nonetheless, the genes and developmental processes that generate wings turn out to be shared between these species. Thus, in cases of deep homology, the developmental mechanisms generating a trait are homologous, but the trait itself is not." (Fitch 2011:136).

The possibility of gaining insights from the search for homologues of the different components of the FLB, among other living organisms, is by now an accepted wisdom, but we hope to extend the search beyond living organisms to encompass the broader natural world. Considerations of this kind have led to a search for language independent principles active in nature, principles that might be deeply grounded in physical law, to paraphrase the way Chomsky (2005) frames the issue, and that might apply to all sort of natural phenomena, including language. An example that comes to mind are the principles of computational efficiency that appear to have a broad range of application in the natural world, from determining the way light travels to regulating insects' navigation. Lewis (2013), for instance, reports the result of a study about the path that fire ants choose on the way to a food source. She points out that "just as light does, ants travelling through different materials follow the fastest path…" The article in question concludes that "Fermat's principle of least time" applies to both light's travel and the path taken by fire ants on their route to a food source. The role of such principles of computational efficiency has been recognized in generative grammar since the

beginning of the Minimalist Program (Chomsky 1995). The question has at time taken the form of investigating what determines the path taken by the displacement operation or fronting of elements (now called Internal Merge) attested in many languages. In English, for instance, the first verbal element of an affirmative sentence, as given by a left to right scan of the linear string of elements, is the one fronted in order to derive a question. Thus, the left-most verbal element in both (30a,b) is respectively fronted to yield (31a,b).

(30)   a.   The child **is** sleeping.
       b.   The child **has** been sleeping

(31)   a.   Is the child __ sleeping?
   b.   Has the child__been sleeping?

In a complex example like that in (32a) below; however, fronting the left-most verbal element (i.e the first *is*) results in an ungrammatical example, as shown in (32b). The right result is obtained if the right-most verbal element (i.e., the second *is* from left to right) is fronted.

(32)   a.   The child who is sleeping is happy.
       b.   *Is the child who __ sleeping is happy?
       c.   Is the child who is sleeping __ happy?

One interesting question that arises in connection with the data in (30)–(32) is how children learn to front the proper verbal element in these types of examples. This question has been investigated through psycholinguistic experiments, designed in order to determine whether children learn to front the proper element in examples like (32) by analogy with simpler examples like those in (31). The results of such experiments show that children do not seem to learn about the proper path of fronting, but rather that such a path is determined by general principles constraining language. If one takes into account the structure of the examples above, one finds that the second *is* in (32a) is structurally closer to the landing site of the fronting operation, so that in fronting this element a child is actually choosing the fastest path to turn the relevant example into a question. From the perspective of the broad comparative method, assumed in the biolinguistic program, the analogy with Fermat's principle of the least time could not be greater: just as it happens with light travel and the choice by ants of a path to a food source, the path taken by the Internal Merge operation in the FLN seems to be the fastest, most efficient one.

Comparative methodology between language and the genetic code may lead to further substantiate the unification of language and biology. The genetic code is nearly universal in the sense that it is nearly used by all known organism, animals, plants, fungi, archaea, bacteria, and viruses. The genetic laws of preservation ensuring the efficient transmission of the pedigree, the genetic heritage, may find their homologue in language Inclusiveness Condition and the No Tampering

condition. According to Chomsky's (1995:225) Inclusiveness Condition, the output of a system does not contain anything beyond its input. This condition implies that the interface levels contain nothing more than arrangements of lexical items. Consequently no traces of displacement or other material introduced in the derivation such as indices may be part of the interfaces. The No Tampering Condition (Chomsky 2008a) also falls into the set of principles of efficient computation. According to this condition, the merger of two syntactic objects, for example [Q] and C in question formation, leaves the two syntactic objects unchanged. Cell division and DNA replication are subject to laws of preservation. Usually, cells divide in identical copies and DNA replication generate identical DNA strands. The comparative methodology may also lead to identify deep homologies between these biological processes and language computation. Current mainstream syntactic theorizing relies on the notion of "phase", as units of derivation and interpretation, and assumes that efficient derivations proceed by phases. *Derivation by phases* limits the search space and the computational load of syntactic computation, (Uriakereka 1998, 1999, 2002; Richards 2006; Chomsky 1995, 2001, 2008a, b, 2013, a.o.). A phase is a unit of derivation and interpretation. It minimally includes a functional head and its complement. It is subject to the Principle of impenetrability, according to which the head and the edge of a phase are the only positions available for the displacement of a constituent outside of a phase. A phase is also a separable semantic and sensorimotor constituent at the interfaces. According to Chomsky (2001, 2008a), phases are propositional. CP and v*P are unanimously recognized as phases, while DP and PP are still under discussion. Morphological constituents have also been argued to be phases (Di Sciullo 2004, 2005; Marantz 2008; Embick 2010, a.o.) Thus, vP is a phase, and the verbal head for vP as well as the phrasal constituent at the edge of the vP are the only constituents that may be displaced to the next phase up. We illustrate this in (33), where the identical copies of the displaced constituents are displayed in strikethrough.

(33)
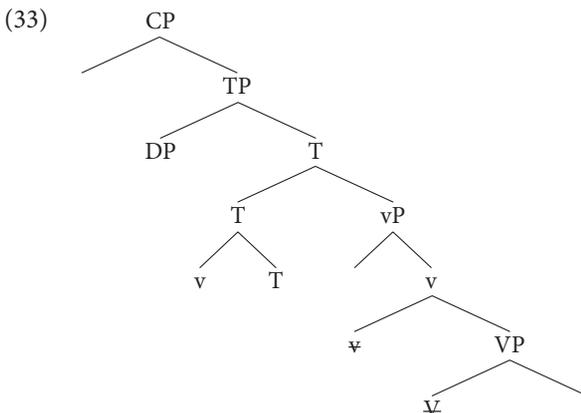
Since phase-based procedures in language are enforced by general principles of efficient computation and economy, and given that such principles can have a broad range of application in nature, it is conceivable that there might be biological processes proceeding in a phase-by-phase fashion.

A comparative approach that searches for potential homologues or analogues of the components of the Language Faculty in other organisms is part and parcel of the biolinguistic research. Several works indicate that the comparative approach also covers the effect of economy principles, including locality, preservation and symmetry breaking principles on the growth and development of biological organisms. These principles rely on the formal properties of the objects and phenomena under scrutiny and contribute to the unification of language and biology.

5.   Summary

The biolinguistic program is a research space dedicated to the study of human language as a biological object. Biolinguistic research relies on current knowledge in linguistics, as well as in biology and neurosciences. As knowledge in these fields evolves, further questions and hypotheses will arise, pushing further explanatory accounts of the biological basis of the human Language Faculty, its emergence, the articulation of FLN and FLB, language phylogeny, language acquisition and variation, as well as principles of efficient computation.

References

Avrutin, S. & Wexler, K. 1992. Development of principle B in Russian: Coindexation at LF and coreference. *Language Acquisition* 2: 259–306. doi:10.1207/s15327817la0204_2

Baauw, S. 1999. The role of the clitic-full pronoun distinction in the acquisition of pronominal coreference. In *Proceedings of the 23rd Annual Boston University Conference on Language Development*, A. Greenhill, H. Littlefield & C. Tano (eds), 32–43. Somerville MA: Cascadilla Press.

Baauw S., Escobar, M. & Philip, W. 1997. A delay of principle B effect in Spanish speaking children: The role of lexical feature acquisition. In *Proceedings of the GALA 97 Conference on Language Acquisition,* A. Sorace, C. Heycock & R. Shillcock (eds), 16–21. Edinburgh: University of Edinburgh.

Bahlmann J., Schubotz R.I. & Friederici, A.D. 2008. Hierarchical artificial grammar processing engages Broca's area. *NeuroImage* 42(2): 525–34. doi:10.1016/j.neuroimage.2008.04.249

Berwick, C.R. 2011. All you need is Merge. All you need is Merge: Biology, computation, and language from the bottom up. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 461–491. Oxford: OUP.

Berwick, R.C., Beckers, G.J., Okanoya, K. & Bolhuis, J.J. 2012. A bird's eye view of human language evolution. *Front. Evol. Neurosci.* 4(5). doi:10.3389/fnevo.2012.00005

Berwick C.R. & Chomsky, N. 2011. The Biolinguistic Program. The current state of its development. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 13–45. Oxford: OUP.

Bickerton, D. 1990. *Language and Species*. Chicago IL: University of Chicago Press.

Boeckx, C. 2011. The emergence of the language faculty, from a biolinguistic point of view. In *The Oxford Handbook of Language Evolution*, M. Tallerman & K. Gibson (eds), 492–201. Oxford: OUP.

Bolhuis, J.J. & Everaert, M. (eds). 2013. *Birdsong, Speech, and Language: Exploring the Evolution of Mind and Brain*. Cambridge MA: The MIT Press.

Byrne, R.W. & Russon, A.E. 1998. Learning by imitation: A hierarchical approach. *Brain and Behavioral Sciences* 21: 667–721.

Chien, Y.C. & Wexler, K. 1990. Children's knowledge of locality conditions in bindings as evidence for the modularity of syntax and pragmatics. *Language Acquisition* 1: 225–295. doi:10.1207/s15327817la0103_2

Chomsky, N. 2015. Problems of projections: Extensions. In *Structures, strategies and beyond: Studies in honour of Adriana Belletti*, E. Di Domenico, C. Hamann & S. Matteini (eds), 1–16. Amsterdam: John Benjamins. doi:10.1075/la.223.01cho

Chomsky, N. 2013. Problems of projections. *Lingua* 130: 33–49. doi:10.1016/j.lingua.2012.12.003

Chomsky, N. 2011. Poverty of the stimulus unfinished business. Ms, MIT.

Chomsky, N. 2008b. The Biolinguistic Program: Where does it stand today? Ms, MIT.

Chomsky, N. 2008a. On phases. In *Foundational Issues in Linguistic Theory. Essays in Honor of Jean-Roger Vergnaud*, R. Freiden, C.P. Otero & M.L. Zubizarreta (eds), 133–166. Cambridge MA: The MIT Press.

Chomsky, N. 2007. Of mind and language. *Biolinguistics* 1: 9–27.

Chomsky, N. 2005. Three factors in language design. *Linguistic Inquiry* 36: 1–22. doi:10.1162/0024389052993655

Chomsky, N. 2001. Derivation by phase. In *Ken Hale: A Life in Language*, M. Kenstowicz (ed.), 1–52. Cambridge MA: The MIT Press.

Chomsky, N. 1995. *The Minimalist Program*. Cambridge MA: The MIT Press.

Chomsky, N. 1988. *Language and Problems of Knowledge*. Cambridge MA: The MIT Press.

Chomsky, N. 1986. *Knowledge of Language: Its Nature, Origins and Use*. New York NY: Praeger.

Chomsky, N. 1981. *Lectures on Government and Binding: The Pisa lectures*. Berlin: Mouton de Gruyter.

Chomsky, N. 1968. *Language and Mind*. New York NY: Harcourt, Brace & World. doi:10.1037/e400082009-004

Chomsky, N. 1965. *Aspects of the Theory of Syntax*. Cambridge MA: The MIT Press. Vol. II, R.D. Luce, R. Bush & E. Galanter (eds), 269–321. New York NY: Wiley & Sons.

Chomsky, N. 1957. Three models for the description of language. *IRE Trans. Inf. Theory* 2: 113–124. doi:10.1109/TIT.1956.1056813

Collins, C. 1997. *Local Economy*. Cambridge MA: The MIT Press.

Coolidge, F.L. & Wynn, T. 2005. Working memory, its executive functions, and the emergence of modern thinking. *Cambridge Archaeological Journal* 15(1): 5–26. doi:10.1017/S0959774305000016

Darwin, C. 1871. *The Descent of Man, and Selection in Relation to Sex*. London: John Murray. doi:10.1037/12293–000

Di Sciullo, A.M. 2014. Minimalism and I-morphology. In *Minimalism and Beyond: Radicalizing the Interfaces* [Linguistic Faculty and Beyond 11], P. Kosta, S. Franks & T. Radeva-Bork (eds), 267–286. Amsterdam: John Benjamins. doi:10.1075/lfab.11.10sci

Di Sciullo, A.M. 2013. Exocentric compounds, language and proto-language. *Language Information Society* 20: 1–26.

Di Sciullo, A.M. 2012. Biolinguistics, minimalist grammars and the emergence of complex numerals. Presented at Theoretical Linguistics/Biolinguistics Workshop (EVOLANG 9), 13 March, Kyoto.

Di Sciullo, A.M. 2011. A biolinguistic approach to variation. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*. A.M. Di Sciullo & C. Boeckx (eds), 305–328. Oxford: OUP.

Di Sciullo, A.M. 2005. *Asymmetry in Morphology*. Cambridge MA: The MIT Press.

Di Sciullo, A.M. 2004. Morphological phases. In *The 4th GLOW in Asia 2003. Generative Grammar in a Broader Perspective*, J.-Y. Yoon (ed.), 113–137. The Korean Generative Grammar Circle and Cognitive Science, Seoul National University.

Di Sciullo, A.M. & Somesfalean, S. 2015. Object pronouns in the evolution of Romanian: a biolinguistic perspective. In Formal approaches to DPs in Old Romanian, V. Hill (ed.), 269–290. Leiden/Boston: Brill.

Di Sciullo, A.M., Nicolis, M. & Somesfalean, S. 2013. Evo-devo language universals. Paper presented at the International Linguists Conference 19, University of Geneva.

Di Sciullo, A.M & Somesfalean, S. 2013. Variation in the Position of the Definite Determiner in Romanian: a Biolinguistic Perspective. Romance Linguistics in the Pacific: Variations in Time and Space. Special Issue of the *Australian Journal of Linguistics 33*(2):121–139. Taylor&Francis.

Di Sciullo, A.M. et al. 2010. The Biological Nature of Human Language. *Biolinguistics* 4: 4–34.

Di Sciullo, A.M. & Isac, D. 2008. The asymmetry of Merge. *Biolinguistics* 2: 260–290.

Di Sciullo, A.M. & Aguero-Bautista, C. 2008. The delay of principle B effect (DPBE) and its absence in some languages. *Language and Speech* 51:77–100. doi:10.1177/00238309080510010601

Embick, D. 2010. *Localism versus Globalism in Morphology and Phonology.* Cambridge MA: The MIT Press. doi:10.7551/mitpress/9780262014229.001.0001

Fitch, W.T. 2011. "Deep homology" in the biology and evolution of language. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 135–166. Oxford: OUP.

Fitch, W.T. & Hauser, M.D. 2004. Computational constraints on syntactic processing in a non-human primate. *Science* 303: 377–380. doi:10.1126/science.1089401

Fox, D. 2000. *Scope and Semantic Interpretation.* Cambridge MA: The MIT Press.

Gallistel, C.R. 1990. *The Organization of Learning.* Cambridge MA: Bradford Books/The MIT Press.

Gopnik, M. 1990. Feature blindness: A case study. *Language Acquisition* 1(2): 139–164. doi:10.1207/s15327817la0102_1

Grodzinsky, J. & Reinhart, T. 1993. The innateness of binding and coreference. *Linguistic Inquiry* 24: 69–102.

Hall, B.K. Descent with modification: The unity underlying homology and homoplasy as seen through an analysis of development and evolution. *Biological Reviews* 78: 409–433. doi:10.1017/S1464793102006097

Hauser, M.D., Chomsky, N. & Fitch, T. 2002. The faculty of language: What is it, who has it, and how did it evolve. *Science* 198: 1569–79. doi:10.1126/science.298.5598.1569

Hauser, M.D. 2000. What do animals think about numbers? *American Scientist* 88(2): 144–15. doi:10.1511/2000.19.863

Hauser, M.D., MacNeilage, P. & Ware, M. 1996. Numerical representations in primates. *Proceedings of the National Academy of Sciences of the United States of America* 93(4): 1514–1517. doi:10.1073/pnas.93.4.1514

Hauser, M.D., Yang, C., Berwick, R.C., Tattersall, I., Ryan, M.J., Watumull, J., Chomsky, N. & Lewontin, R.C. 2014. The mystery of language acquisition. *Frontiers in Psychology* 5. doi:10.3389/fpsyg.2014.00401

Hornstein, N. & Uriagereka, J. 2002. Reprojections. In *Derivation and explanation in the Minimalist Program*, S. Epstein & T. Seely (eds), 106–132. Malden MA: Blackwell. doi:10.1002/9780470755662.ch6

Huang, J. 1998[1982]. *Logical Relations in Chinese and the Theory of Grammar*. New York NY: Garland.

Hurford, J.R. 2014. *Origins of Langage. A Slim Guide*. Oxford: OUP.

Jackendoff, J.R. 2011. What is the human language faculty: Two views? *Language* 87(3): 586–624. doi:10.1353/lan.2011.0063

Jenkins, L. 2011. Biolinguistic investigations: Genetics and dynamics. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 126–134. Oxford: OUP.

Jenkins, L. 2000. *Biolinguistics: Exploring the Biology of Language*. Cambridge: CUP. doi:10.1017/CBO9780511605765

Kayne, R. 2011. Why are there no directionality parameters? In *Proceedings of the 28th West Coast Conference on Formal Linguistics*, M. Byram Washburn, K. McKinneyBock, E. Varis, A. Sawyer & B. Tomaszewicz (eds), 1–23. Somerville MA: Cascadilla Press.

Kayne, R. 1994. *The Antisymmetry of Syntax*. Cambridge MA: The MIT Press.

Koster, C. 1993. *Errors in Anaphora Acquisition*. Ph.D. dissertation, Utrecht University.

Larson, R. 2011. Clauses, propositions and phases. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 366–391. Oxford: OUP. 366–391.

Lasnik, H. 2011. What kind of computing device is the human language faculty. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 354–365. Oxford: OUP.

Lenneberg, E.H. 1967. *Biological Foundations of Language*. New York NY: Wiley & Sons.

Lewontin R.C. 2000. *The Triple Helix: Gene, Organism and Environment*. Cambridge MA: Harvard University Press.

Levin, M. & A.R. Palmer. 2007. Left-right patterning from the inside out: Widespread evidence for intracellular control. *BioEssays* 29: 271–287.

Lewis. T. 2013. Ants 'use math' to find fastest route. *Livescience*. ⟨http://www.livescience.com/28795-ants-find-fastest-route-using-math.html⟩

Lewontin R. 2004. Response to 'Selection for Asymmetry". *Science* 306: 812. doi:10.1126/science.306.5697.812

Li, R. & Bowerman, B. 2010. Symmetry breaking in biology. *Cold Spring Harbor Perspectives in Biology* 2(3): A003475. doi:10.1101/cshperspect.a003475

Lightfoot, D. 1991. *How to Set Parameters. Arguments from Language Change*. Cambridge MA: The MIT Press.

Lightfoot, D. 1982. *The Language Lottery. Toward a Biology of Grammars*. Cambridge MA: The MIT Press.

Lightfoot, D. 1979. *Principles of Diachronic Syntax*. Cambridge: CUP.

McKee, C. 1992, A comparison of pronouns and anaphors in Italian and English acquisition. *Language Acquisition* 2: 21–54. doi:10.1207/s15327817la0201_2

Marantz, A. 2008. Phases and words. In *Phases in the Theory of Grammar*, S.-H. Choe (ed.), 191–222. Seoul: Dong In.

McGonigle, B., Chalmers M. & Dickinson, A. 2003. Concurrent disjoint and reciprocal classi-fication by Cebus Apella in seriation tasks: Evidence for hierarchical organization. *Animal Cognition* 6:185–197. doi:10.1007/s10071-003-0174-y

Nobrega, V.A. & Miyagawa, S. 2015. The precedence of syntax in the rapid emergence of human language in evolution as defined by the Integration Hypothesis. *Frontiers Psychology* 6: 271.

Moro, A. 2000. *Dynamic Antisymmetry*. Cambridge MA: The MIT Press.

Musso, M., Moro, A., Glauche, V., Rijntjes, M., Reichenbach, J., Büchel, C. & Weiller, C. 2003. Broca's area and the language instinct. *Nature Neuroscience* 6(7): 774-781. doi:10.1038/nn1077

Palmer, R. 2009. Animal asymmetry. *Current Biology* 19(12): 473–477. doi:10.1016/j.cub.2009.04.006

Palmer, A.R. 2004. Symmetry breaking and the evolution of development. *Science* 306: 828–833. doi:10.1126/science.1103707

Palmer, A.R. 1996. From symmetry to asymmetry: Phylogenetic patterns of asymmetry varia-tion in animals and their evolutionary significance. *Proceedings of the National Academy of Sciences* (USA) 93: 14279–14286.

Philip, W. & Coopmans, P. 1996. The role of lexical feature acquisition in the development of pronominal anaphora. In *Amsterdam Series on Child Language Development* 5, W. Philip & F. Wijnen (eds). Amsterdam: University of Amsterdam.

Piattelli-Palmarini, M. (ed.). 1980. *Language and Learning: The Debate between Jean Piaget and Noam Chomsky*. Cambridge MA: Harvard University Press.

Piattelli Palmarini, M. & Uriagereka, J. 2011. A geneticist's dream, a linguist's nightmare: The case of FOXP2. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 100–125. Oxford: OUP.

Piattelli-Palmarini, M. & Berwick, R.C. (eds). 2013. *Rich Languages from Poor Inputs*. Oxford: OUP.

Pinker, S. 1994. *The Language Instinct: How the Mind Creates Language*. New York NY: HarperCollins.

Pinker, S. & Bloom, P. 1990. Natural language and natural selection. *Behavioral and Brain Sci-ences* 13(4): 707–78. doi:10.1017/S0140525X00081061

Poeppel, D. & Embick, D. 2005. Defining the relation between linguistics and neuroscience. In *Twenty-First Century Psycholinguistics: Four Cornerstones,* A. Cutler (ed.), 103–118. Mahwah NJ: Lawrence Erlbaum Associates.

Progovac, L. 2015. *Evolutionary Syntax*. Oxford: OUP. doi:10.1093/acprof:oso/9780198736547.001.0001

Progovac, L. 2007. Grammars within without recursion: Implications for evolutionary stud-ies. Paper presented to Illinois State University Conference on Recursion in Human Lan-guages, Normal IL.

Progovac, L. 2006. The syntax of nonsententials: Small clauses and phrases at the root. In *The Syntax of Nonsententials* [Linguistik Aktuell/Linguistics Today 93], L. Progovac, K. Paesani, E. Casielles & E. Barton (eds), 33–71. Amsterdam: John Benjamins. doi:10.1075/la.93.04pro

Richards, N. 2002. Very local A' movement in a root-first derivation. In *Derivation and Explanation in the Minimalist Program,* S.D. Epstein & T.D. Seely, 227–245. Oxford: Blackwell. doi: 10.1002/9780470755662.ch10

Richards, N. 2006. Deriving the edge: What's in a phase? Ms, University of Cambridge.

Rizzi, L. 1990. *Relativized Minimality*. Cambridge MA: The MIT Press.

Roberts, I. 2011. Parametric hierarchies: Some observations. Presented at the workshop on linguistic variation and the minimalist program, Universidad Autonoma de Madrid.

Roberts, I. 2007. *Diachronic Syntax*. Oxford: OUP.

Roberts, I. & Roussou, A. 2003. *Syntactic Change: A Minimalist Approach to Grammaticalization*. Cambridge: CUP. doi: 10.1017/CBO9780511486326

Rugani, R., Vallortigara, G., Vallini, B. & Regolin, L. 2011. Asymmetrical number-space mapping in the avian brain. *Neurobiology of Learning and Memory* 95: 231–238. doi: 10.1016/j.nlm.2010.11.012

Rugani, R., Fontanari, L., Simoni, E., Regolin, L. & Vallortigara, G. 2009. Arithmetic in newborn chicks. *Proceedings of the Royal Society of London B, Biological Sciences* 276: 2451–2460. doi: 10.1098/rspb.2009.0044

Schino, G., Tiddi, B. & di Sorrento, P. 2006. Simultaneous classification by rank and kinship in Japanese macaques. *Animal Behaviour* 71: 1069–1074. doi: 10.1016/j.anbehav.2005.07.019

Seyfarth, R.M., Cheney, D.L. & Bergman, T.J. 2005. Primate social cognition and the origins of language. *Trends in Cognitive Sciences* 9(6): 264–266. doi: 10.1016/j.tics.2005.04.001

Shubin, N., Tabin, C. & Carroll, S. 1997. Fossils, genes and the evolution of animal limbs. *Nature* 388: 639–648. doi: 10.1038/41710

Uriagereka, J. 2008. *Syntactic Anchors. On Semantic Structuring*. Cambridge: CUP. doi: 10.1017/CBO9780511481482

Uriagereka, J. 2002. *Derivations*. London: Routledge.

Uriagereka, J. 1999. Multiple spell-out. In *Working Minimalism*, S.D. Epstein & N. Hornstein (eds), 251–282. Cambridge MA: The MIT Press.

Uriagereka, J. 1998. *Rime and Reason*. Cambridge MA: The MIT Press.

Wexler, K. 1998. Very early parameter setting and the unique checking constraint: A new explanation of the optional infinitive stage. *Lingua* 106: 23–79. doi: 10.1016/S0024-3841(98)00029-1