A Short History of Biolinguistics

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1. What is biolinguistics, whose history deserves to be written?

Unlike most scientific disciplines, the origin of biolinguistics is so recent that, to a large extent, its history has been written by some of its main protagonists, and not by historians who have approached it from outside of the discipline, or that have done it long after the period of its development. Therefore, this brief summary of the history of biolinguistics is centrally based on the narratives of some of its protagonists, such as Noam Chomsky, Massimo Piatelli-Palmarini, Lyle Jenkins or Tecumseh Fitch, among others. Thus, the only originality of this chapter will be the selection of topics considered and the emphasis on certain authors more than others.

The authors of "The Biolinguistics *manifesto*" (Boeckx & Grohmann 2007), which constitutes the editorial of the first issue of the journal *Biolinguistics*, founded in 2007 (an important milestone in the history of our discipline), claim that there are two possible meanings of the word *biolinguistics*, a weak sense and a strong sense. The weak sense of the term refers to what they call "business as usual" for linguists, that is, the investigation of the structure of language following the program of Generative Grammar founded by Chomsky in the 1950s, while the strong sense refers to attempts to solve research questions about language "that necessarily require the combination of linguistic insights and insights from related disciplines (evolutionary biology, genetics, neurology, psychology, etc.)" (Boeckx & Grohmann 2007: 2). Although Boeckx and Grohmann are quick to say that they do not consider the adjective *weak* to indicate that linguistic theory is "inferior" to interdisciplinary work, and that it is the basis of most interdisciplinary studies, one may wonder who would want the weak version of something if there is a strong version.

For that reason, in this summary of the history of biolinguistics I suggest using different expressions to refer to these two different ways of understanding it: biolinguistics in the narrow sense (instead of *weak*) and biolinguistics in the broad sense (instead of *strong*). This modification is not merely terminological, but is based on the conviction that biolinguistics in the narrow sense is the scientific core of biolinguistics, and that interdisciplinary work (and more properly biological in the traditional sense of the term), that is, biolinguistics in the broad sense, is only possible if it is integrated with the first one. In fact, the distinction between two types of biolinguistics, although it may be useful, is purely arbitrary, like the distinctions we establish using adjectives such as *mental*, *physical*, *natural* or *material* to characterize the nature of the objects of study of scientific disciplines. Whether something is considered mental, physical, natural or material does not depend on the properties of the object in question, but on the degree of development of the theories we use. As Richard Feynman (1963) pointed out, "if our small minds, for some convenience, divide this glass of wine, the universe, into parts—physics, biology, geology, astronomy, psychology, and so on—remember that nature does not know it!".

It is no coincidence that Chomsky's commitment throughout his career has always been with methodological naturalism (e.g. Chomsky 2000), and not so much with the determination of whether linguistics is part of psychology, biology or physics. When Chomsky was asked about the two meanings of biolinguistics in the *Manifesto*, and about some observations according to which the term biolinguistics should stop being used as a synonym for generative grammar (e.g. Martins & Boeckx 2016), he answered: "I don't see much of an issue. Biological investigation of the language faculty is, by definition, an approach to investigation of the language faculty. Generative grammar is the study of core properties of the language faculty. Why should any issue arise?" (*apud* Trettenbrein 2017: 492).

The story I am going to tell is that of biolinguistics in the narrow sense, that is, linguistic theory understood as a part of natural science. In fact, it seems clear that it is not possible to study the biology of language in any other way[1]. As McGilvray has pointed out, although there are various ways to study how language is related to biology, "few, however, proceed on the assumption that language is a biologically based 'organ' inside the head of humans" (McGilvray 2013: 22).

Although methodological naturalism is necessary, it is obviously not sufficient. To get an idea of the difficulties, let's recapitulate Chomsky's typical reasoning: Since the object of study of the linguist is a "mental organ" and since the mental—contrary to what Descartes said—is one more dimension of the natural (like the chemical or the electrical), then linguistics is a branch of natural science, a kind of "abstract biology". This reasoning may be logically flawless, but leaves us with an explanatory gap. The rest of the chapters in this volume constitute an attempt to show what paths are open to bridge that gap.

Of course, it is worth remembering that Steven Weinberg, Nobel laureate and one of the fathers of the standard model of quantum mechanics, said that what is real is what a coherent theory claims to be real (Weinberg 1992). When we consider quantum physics it does not make sense to say that entities are first postulated and then confirmed by finding their "material" correlates. It makes no sense to talk about material correlates of the Higgs boson or other particles and fields, since these are postulated to explain what it is that we call "matter". Physics is empirical in a deeper sense: the postulates of physics acquire reality, existence, not when their "material" reality is experimentally discovered, which is absurd when speaking of wave functions or superstrings, but when the theories of which such postulates are part of are the simplest and most elegant theories among those that adequately predict the behavior of the observable world.

The same should apply to the study of language, if we are really serious about the naturalistic approach. But many scientists object that the type of evidence that

[1] As Chomsky remarks, "individuals can choose their own research interests and projects. Clearly, however, the domain of 'strong' biolinguistics, as defined, can be pursued only to the extent that 'linguistic insights'—that is 'properties of grammar'—have been developed sufficiently to be combined and integrated" (*apud* Trettenbrein 2017: 492).

supports linguistic theories is not "real" because it does not have a clear biological (neurological, genetic or molecular) support. But note that then we would be limiting the capacity of one science based on the underdevelopment of others. If we required linguistic theory to be formulated in terms of psychological, neurological or biological reality, central concepts in linguistic theory, such as morpheme, phrase or adjective, simply would not have been formulated. The effect would be that the study of language simply could not be done scientifically. We would be back in dualism or, as Chomsky often says, facing a double standard depending on whether we study the body "from the neck up" or "from the neck down."

Of course, natural sciences have to explain language (and mind, and consciousness, and intentions), but they have to do so by expanding as they try to support the more abstract sciences. The desired integration of linguistics into biology cannot be done by attempting to translate linguistic principles and entities into biological principles and entities, but by expanding biology. The main problem is that between "cannibal reductionism" and genuine scientific unification there is a gap that, if not filled with novel empirical research, performs the same function as traditional dualism, isolating the fields in mutual infertility.

Therefore, what we informally call biolinguistics in the broad sense is not a complement or alternative to biolinguistics in the narrow sense, but rather its natural development. Integration within more basic sciences (such as neuroscience or developmental biology) is the natural consequence of progress in the development of biolinguistics in the narrow sense, and of the possible explanatory connections that can be established between biolinguistics and other biological disciplines, or with the so-called natural sciences in general (see Fernández Pérez, this volume).

As Chomsky has also repeatedly pointed out (for example Chomsky 2004), the integration of chemistry into physics involved a profound revolution in physics (not in chemistry), and hopefully biolinguistics and the abstract study of cognitive systems will play a similar role in the biological sciences, if they are to be able to help us answer the central questions that characterize biolinguistics, as formulated by Chomsky (for example Chomsky 1988)[2]:

1. What constitutes knowledge of language? (Humboldt's problem)
2. How is this knowledge acquired? (Plato's problem)
3. How is this knowledge put to use? (Descartes' problem)
4. How is this knowledge implemented in the brain? (Broca's problem)
5. How did this knowledge evolve in the species? (Darwin's problem)

Note that questions 2-5 only make sense if we assume that the object of study mentioned in question 1, language knowledge, is a natural object. Approaches that consider languages as purely cultural objects, as social institutions, or as the result of behavior cannot ask the rest of the questions in the same way (and in some

[2] The reference to each question with the name of a relevant author (proposed by Chomsky himself for the first three questions) not only serves as a convenient abbreviation, but is a tribute to predecessors, and a sign that the roots of the new science of language that we call biolinguistics are actually very deep in time.

cases not at all). It is obvious that question 1 (the specific research program of biolinguistics in the narrow sense) has a logical priority over the others. To study how an object develops, how it is used, how it is physically implemented, or how it has evolved, we need a solid, empirically grounded theoretical model of language knowledge, that is, of the structure of the language faculty (both in the initial state and in the steady state). Besides, a deep understanding of this object can only come through the answers we can provide to the rest of the questions, which necessarily involve the unification of linguistic theory with more basic scientific disciplines, such as psycholinguistics, neurolinguistics, neurobiology, genetics, developmental biology and evolutionary biology. Thus, although biolinguistics in the narrow sense tends to correspond to question 1, and biolinguistics in the broad sense tends to correspond to questions 2-5, they are in fact one and the same science, insofar as a theory about 1 is indispensable for progress on the remaining questions, but such a theory is clearly incomplete (and largely unfalsifiable) without the answers to the other questions.

Biochemistry is not really "the biology of chemistry", but the "chemistry of life". Similarly, we can say that biolinguistics is a "linguistics of life" (a theory of natural language) that opens the way to a biology of language, to an understanding of the biological basis of language. Consequently, the story to be told in the following pages is a story of how developments in linguistic theory have increased our ability to provide answers to all the questions posed and, simultaneously, of how the evolution of biology has influenced linguistic theory itself.

2. Chomsky, Lenneberg and the foundation of linguistics as a natural science: consolidating descriptive adequacy

There seems to be a certain consensus among those who have considered this issue in assuming that biolinguistics emerged from the work of two "founding fathers", Noam Chomsky and Eric Lenneberg: "Some sixty years ago, when they were still graduate students, Chomsky and Lenneberg decided to find out what the biological foundations of the human linguistic capacities were, and in so doing created the field of biolinguistics" (Boeckx & Grohmann 2007: 1)[3].

This "double foundation" fits well with the conclusion of the previous section, according to which narrow and broad biolinguistics are not competitors, but rather they need each other. There also seems to be a consensus that the foundational works of the new discipline are, on the one hand (as far as narrow biolinguistics is concerned), *The Logical Structure of Linguistic Theory*[4], and on the other hand (as far as broad biolinguistics is concerned), Lenneberg's monumental 1967 book *Biological Foundations of Language*[5].

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3 As Jenkins (2000: 1 ff.) points out, questions 1-5 above were already the subject of discussion among graduate students in Chomsky's academic circle in the early 1950s, including Eric Lenneberg, Morris Halle or Yehoshua Bar-Hillel.

4 A 1955 manuscript by Chomsky published in full only in 1975, but which was quite influential thanks to copies circulating in certain circles and parts of it being published as the 1957 book *Syntactic Structures*.

5 Fitch also shares that view: "although he apparently did not adopt the term 'biolinguistics' himself, Eric Lenneberg can rightly be seen as an important founding father of contemporary biolinguistics" (Fitch 2017: 445).

Thus, the origin of biolinguistics coincides with that of generative grammar, which, in turn, is a crucial part of the development of the so-called "cognitive revolution". A central consequence of the cognitive revolution is precisely the conception of language as a natural object (a part of human biology) and of linguistics as a natural science. As Chomsky declared in an interview in 1968, linguistics "is really a theoretical biology, if you like, a theoretical psychology" (quoted by Jenkins 2000: 3).

"Classical" Chomskyan linguistic theory (Chomsky 1955/1975, 1957, and 1965) suggested, perhaps for the first time in history, central properties of the human faculty of language (FL) that raised, in turn, important questions for biology. Not coincidentally, Lenneberg's book (which includes an appendix by Chomsky entitled "The formal nature of language") addressed many of the issues that we will see developed by biolinguistics in the coming decades, such as the notion of the critical period for language acquisition, the argument of the poverty of stimulus, the genetic basis of language acquisition and language deficits, twin studies, the development of language in deaf children, the relationship between language and brain, the study of the development of feral children, and the evolution of language. As Balari (2012), Trettenbrein (2017), and Fitch (2017) have pointed out, Lenneberg's contribution to these issues was novel and inspiring, and his insights and proposals have stood the test of time with surprising solidity since 1967, despite the enormous change in some biological disciplines in that period, including genetics, developmental biology or brain imaging techniques (as shown in other chapters in this volume).

A common basis for Chomsky's and Lenneberg's conceptions of language is the influence of European ethologists, less well known in the United States at the time (both Lenneberg and Halle spoke German). In his famous review of B. F. Skinner's book *Verbal Behavior*, Chomsky (1959) expressly relies on contributions by Lorenz and Tinbergen, among others, to defend the existence of urewarded learning, both in other animals (as in the case of bird song) and in humans, and in general to defend the idea that the existence of innate biases in learning systems are common in other species, and it would not be mysterious if this were also the case in human language.

Another early connection of Chomsky's in relation to biology is seen in his observations, already in Chomsky (1966), on the possible relation between the notion of Universal Grammar (UG), conceived of as the set of principles determining the class of possible languages, and Goethe's theory of the *Urpflanze*, a kind of theoretical primordial plant from which all other plants would be derived, and which functions as a constant factor underlying the form of all existing plants, that would be superficially modified as a consequence of variation in environmental conditions. The logic of this approach is clearly related to the model that would eventually be developed in the 1980s, and that we know as the Principles and Parameters (P&P) model, to which we return in the following section.

As Jenkins (2000: 4) insightfully points out, Chomsky and Lenneberg's naturalistic conception of language encountered much more contestation in the fields of psychology and the social sciences, including linguistics, than among some of the most influential biologists of the time. Thus, in the 1970s Chomsky's naturalistic approach and the general structure of the language faculty that the so-called "standard model" of generative grammar (Chomsky 1965) had postulated were well known to molecular biologists (Nobel laureates) Jacques Monod, François Jacob, or Salvador Luria (with whom Chomsky taught a weekly seminar on biolinguistics at MIT in the 1970s). In these years we find opinions of these authors supporting the naturalistic view of biolinguistics. Thus, Monod maintained that it was not surprising that "the linguistic capacity revealed in the course of the brain's epigenetic development is today part of 'human nature', itself defined within the genome in the radically different language of the genetic code" (Monod 1974, *apud* Jenkins 2000: 4, where the reader can find references to similar statements by Jacob, Luria, or the immunologist Niels Jerne).

An atmosphere of collaboration between linguistics and biology crystallized in certain circles in the 1970s, as reflected in an interdisciplinary meeting in May 1974 sponsored by The Royaumont Center for a Science of Man and organized by the physicist and biochemist Massimo Piatelli-Palmarini (who is credited with having coined the very term *biolinguistics* in its current use)[6]. At this meeting, Chomsky and Luria discussed with participants from fields as diverse as neurophysiology, biology, linguistics, psycholinguistics, psychology and mathematics the possibilities of collaboration on various topics, mainly the relationship between brain and language. Following that meeting, Luria and Chomsky (sponsored by the same French institution) organized another meeting in Paris in 1975 attended by renowned biologists such as Jean-Pierre Changeux, Jacques Mehler, Klaus Scherer, Antoine Danchin and Jean Petitot, or influential psychologists such as Jean Piaget.

Jenkins (2000) reports on other conferences and initiatives in this "golden age" of biolinguistics (including the failed launching of a specific journal on the subject) which, in any case, can be considered premature, probably due to the lack of development of linguistic theory and of the biological sciences involved in questions 2 to 5. As one of the protagonists of that period of certain splendor of biolinguistics in the broad sense points out, "in hindsight, almost 40 years later, one must confess that the development of biolinguistics has indeed been slow, though fascinating, and that it's still an inchoate field of inquiry. Inevitably, as time went by, it has been conditioned by several major changes in biology, in linguistics, and in the difficulty in bridging the gap between them" (Piatelli-Palmarini 2013: 13).

As Chomsky acknowledges, it is debatable whether there really was a "cognitive revolution" but, as we have seen, there was a major shift in perspective in linguistics "from the study of behavior and its products (such as texts), to the inner mechanisms that enter into human thought and action" (Chomsky 2004: 381-382). Thus, the cognitive perspective does not consider behavior (or its results) as the

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6 See Jenkins (2000) for a detailed documentation of previous uses of the term (and its *bio-linguistics* variant).

object of study, but as the source of data to build theoretical models of the inner mechanisms of mind that generate expressions[7].

The construction of these theoretical models revealed that even the most studied Western languages have properties that had gone unnoticed even to the most comprehensive and detailed traditional grammars, namely properties derived from the discovery that grammatical rules are structure-dependent, and that linguistic expressions, contrary to appearances, are not linear sequences, but hierarchical structures (see Everaert *et al*. 2015). Therefore, the main objective of the new generative grammar was to reach certain levels of descriptive adequacy based on the study of the mechanisms that create the expressions, and not on their superficial analysis. The efforts of generative grammar focused, therefore, on building an articulated theory of language knowledge capable of predicting the form and meaning of grammatical sentences in a given language.

But, as Chomsky himself has pointed out, precisely because it is a biological theory, "a genuine theory of language has to satisfy two conditions: 'descriptive adequacy' and 'explanatory adequacy'" (2004: 385). As the same author states, the descriptive adequacy condition "holds for a grammar of a particular language, of what the speaker of a language knows", while the explanatory adequacy condition "holds for the general theory of language, universal grammar" (*ibid*.). To satisfy this condition, the various possible languages must be able to be derived from UG (understood as the initial state of the FL) as specific instantiations of the uniform initial state, and as a result of differences in the developmental process caused by experience. To the extent that the theory satisfies the condition of "explanatory adequacy" (which I use in quotation marks because it should be understood in a restricted sense, referring only to problem 2, but not to the others, which would remain unexplained), it solves what has been called "the paradox of language acquisition" (Jackendoff 1994).

The tension characteristic of linguistic theory between the uniqueness of language and the diversity of languages is actually a tension between the two types of adequacy. The search for descriptive adequacy led the models of the 1960-70s to an increase in complexity and rule types, while the search for explanatory adequacy pushes toward a conception of language structure as essentially uniform. It is that goal that leads us to the P&P model and its relation to developmental biology.

3. Principles & Parameters, developmental biology and immunology: searching for "explanatory adequacy"

As Piatelli-Palmarini (2013: 13ff) relates, the pioneering work of Monod and Jacob had pushed developmental biology forward by discovering that genes could be turned on or off by other genes, so that one DNA string could control the expression of another DNA string. Even more remarkably, Jacob had emphasized the universality of the basic molecular components of all life forms, and the crucial

[7] On the origins of Chomsky's ideas about the generative and recursive nature of rule systems, based on mathematical logic and the theory of computation, see Lobina (2014).

role in evolution of the recombination of the fundamental bricks, an idea reflected in Monod's famous quote, "what is true for the colon bacillus is true for the elephant" (Monod *apud* Berwick & Chomsky 2011: 28). Piatelli-Palmarini reports that this idea suggested to Chomsky the idea of parametric variation as a model of human language development and variation[8]. Thus, the intuition of Jacob and Monod (later confirmed by the advance of the new developmental biology) that small differences in the timing and arrangement of the regulatory mechanisms that activate genes could result in remarkable differences in the final phenotype, has a relevant parallel with the essential logic of the P&P model (Chomsky 1981, Chomsky & Lasnik 1993).

This model is based on the assumption that the different types of human languages are the consequence of a developmental system conceived of as a set of invariable (universal) principles connected to a metaphorical "switchbox of parameters", so that the process of language development in children could be assimilated to the task of using the available information in the environment to set the parametric options corresponding to each type of language. For example, to cite one of the most discussed parameters (and simplifying the explanation), children would have to determine whether the language they are learning is head-initial (like Spanish, which would order the verb and object as VO: *eat apples*) or head-final (like Japanese, which would order them as OV: *apples eat*), but children would not have to figure out what a head is, nor that all syntactic projections have a head, since that principle would be invariant and thus part of the initial state of the FL.

As in the case of readjustment of regulatory mechanisms, this linguistic approach proposes a general framework to explain how the essential unity of the FL can give rise to the appearance of exuberant diversity among languages. Moreover, by placing acquisition theory in the context of selective theories of development (as opposed to instructive theories, a difference to which we return below), the P&P model could be considered a move toward greater explanatory adequacy, by providing a more plausible model of language acquisition without postulating the learning of the complex and language-specific rule systems employed in the so-called standard theory to characterize the grammatical structure of human languages.

The search for "explanatory adequacy" (as far as question 2 is concerned) and the inspiration of developmental biology caused linguistic theory to renounce the assumption of the standard model (inherited from the structuralist tradition) that languages are complex systems of rules, in favor of the P&P model, which rejects the traditional concept of grammatical construction as a theoretical primitive. Grammatical constructions come to be conceived of as "taxonomic artifacts", equivalent in biology to concepts such as "terrestrial mammal" (Chomsky 2004: 384), that is, notions useful for description but without theoretical standing. The rules are decomposed into general principles of the language faculty, from whose interaction the different constructions we find in linguistic expressions arise. As Chomsky pointed out, echoing insights from developmental biology, "small

[8] The idea appears already in Chomsky's 1979 Kant Lectures at Stanford, which are collected in the book *Rules and representations* (Chomsky 1980).

changes in switch settings can lead to great apparent variety in output, as the effects proliferate through the system" (Chomsky 2004: 384).

Piatelli-Palmarini (1989) has pointed out that the development of the P&P model is consistent with a similar transition in the biological sciences from instructive to selective models, although in this case, rather than a direct influence, there is a parallel evolution, no less significant for the history of biolinguistics. The comparison was expressly established by immunologist Niels K. Jerne, who titled his Nobel Prize lecture *The Generative Grammar of the Immune System*. Jerne's analogy is rather metaphorical: it is based on the notion of a generative grammar as a system of knowledge that allows the speaker to generate sentences appropriate to new situations, and to understand sentences never heard before. As Jerne points out, the immune system is generative because it is able to find an adequate response to any antigen it faces, even though the antigen has never been encountered before.

What is relevant, and mysterious, is how these processes happen: how the immune system "learns" to create the right molecule (the antibody) for whatever antigen (stimulus) it faces, and how the human brain "learns" a generative knowledge system from the limited linguistic stimuli of the environment. In both cases, and independently in each field, science has shown that the word "learn" is probably not the right one, at least in the sense in which it is traditionally used. The relation between the immune system and language is based on a parallelism suggested by Piattelli-Palmarini (1989) in relation to two basic models of biological evolution and development: the instructive model and the selective model.

The essential idea of an instructive model is that external stimuli give their character to the receiving system, that is, the system somehow extracts its structure from external stimuli. In a selective model, on the contrary, the stimuli also act on a system, but the system is already structured, so that it detects the stimuli in the environment and selects the relevant ones. The difference between both models can be further clarified if we turn to the definitions of molecular biologist Antoine Danchin: "Instructive theories postulate the existence of a causal agent, exterior to the system, that directs its evolution [...] Selective theories, on the opposite, leave to *contingent* interactions the *only* driving force that makes systems evolve" (*apud* Piatelli-Palmarini 1989: 28)[9].

Piattelli-Palmarini suggests that the common fate of Jerne and Chomsky has been that in both cases they have favored the transition from instructive models to selective models. In fact, Jerne received the Nobel Prize in medicine in 1984 precisely for his contribution to a selective theory of the immune system. In Chomsky's case, as is well known, this transition occurs with the rejection of the empiricist conception of language acquisition, according to which the brain builds the knowledge system extracting its structure from the linguistic data of the

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9 A more informal way of understanding the difference between one model and another, also suggested by Piattelli-Palmarini, may be to consider the difference between buying a coat in a department store or ordering it from a tailor. In the first case, the customer selects the coat that best suits her from among the available sizes (a selective process), while in the second case the tailor measures the client and makes a custom-made one (an instructive process). The common sense notion of learning corresponds to the instructive model.

environment, through general learning procedures (such as induction, analogy or imitation). This view is opposed by the "argument of the poverty of stimulus" (Plato's problem): the information provided by the linguistic stimuli that the child receives is insufficient to justify the entire structure of the knowledge system finally obtained, so it must be postulated that some essential principles of the structure of that knowledge system are already part of the organism. If we return to the coat analogy, the question would be whether the child's brain makes a custom-made coat to the stimulus of the environment or, on the contrary, selects one of the available coats, depending on the "form" of the stimulus. Chomsky's answer is the second, so unintuitive that even today it is fiercely rejected. But the answer that modern immunology offers, while fully accepted, is no less counterintuitive than Chomsky's one.

As Jerne points out in his lecture, the adaptive immune system is an organ made up of cells called lymphocytes, which in a human being are around 1% of the body mass, in an estimated number of about 10^{12} units (that is, more numerous than neurons). Lymphocytes (B lymphocytes in particular) are capable of generating specific antibodies for each type of antigen. There are no generic antibodies, but each antibody is specific for each possible antigen. The system is adaptive in the sense that the organism stores memory of previous attacks, so that in a subsequent infection the response is faster and more effective (which is the basis of vaccine immunization). The most surprising thing is that the adaptive immune system works as a selective model and not, as expected, as an instructive one.

Intuitively, since the immune system is capable of creating a specific antibody for each possible antigen, including those that it has not found before, and including those that are new (that is, that have never been found before in previous evolutionary stages, because they have been created in the laboratory), it is logical to think that the immune system behaves according to an instructive model: the antigen molecule determines the structure of the antibody molecule that has to bind it (so that later the invader is destroyed). That is, the system would somehow "learn" what is the structure of the harmful molecule to make it a "tailored coat". But what immunologists (led by Jerne) discovered is that the immune system has already prepared the possible antibodies that it will need. Jerne points out that human lymphocytes can create about 10 million different antibodies[10]. According to Jerne, the immune system is "complete", that is, it can respond with specific antibodies "to any molecule existing in the world, including molecules that the system has never before encountered" (Jerne 1985: 1059). Contrary to intuition, the adaptive immune system works as a selective system.

A parallelism with generative grammar is difficult to avoid at this point. Evidence based on common sense and observation of the progressive learning of children's language, apparently parallel to the development of other capacities, leads to the well-known conclusion in terms of instructive learning. But, just as it happens in the field of evolutionary theory or immunology, we are left without an explanation of how the development processes really happen: how an organism "learns" to

[10] The incommensurability of the figure can be better assessed if we consider that the human body creates "only" about 10,000 different types of proteins, including all hormones, enzymes, etc.

have wings, how it "learns" to generate adequate antibodies to each pathogenic element, or how it "learns" to speak the language of the environment.

Nowadays all immunologists accept that an organism has innately incorporated the capacity to generate the repertoire of antibodies, and that this repertoire is capable of finding an antibody for each antigen that is presented, either natural or artificial, whether it is part of its evolutionary history or not. An important conclusion of this state of affairs is that if the organism were to encounter an antigen that, against all probability, did not have its "image" in the expected 10 million antibodies, the organism simply could not do anything against it. To quote again Piattelli-Palmarini, "a really new antigen would be literally invisible to the immune system: the organism would develop no response to it. This is, typically, a *selective* theory" (1989: 23).

The same is true in the linguistic field: the existence of an innate UG is considered implausible compared to the most economical option of a reduced number of multifunctional learning principles that build each language in people's minds by copying them from the environment. But we know that common sense is not the key to scientific understanding (although it is very useful for everyday life). There is every reason to think that in cognitive science there has also been a transition from instructive learning models to selective learning models. Today it is widely assumed that there is an innate component in cognitive functions such as vision, memory or emotions, so language should not be an exception. Of course, in the case of language we cannot literally apply the analogy with the immune system. We cannot postulate that the human genome carries the more than 6,000 existing languages from which one (or more than one) is selected depending on the stimuli of the environment. Languages are not innate. What could be innate are the principles that determine how they are built. The same is true in immunology: the 10 million different antibodies could not be encoded in just 20,000 genes in the human genome.

For sure, there are numerous aspects of languages that speakers learn from the environment by imitation, analogy, and induction. The point is that not everything that constitutes a human language can be learned in this way. As Fitch wisely remarks, "despite its tiresome persistence, 'nature versus nurture' is a sterile conceptual dead-end, and any valid answer must consider 'nature via nurture' in some form or other" (Fitch 2009: 303). Many aspects of language cannot be learned from the environment if the organism does not severely restrict the possible options, both in the field of lexicon (what types of possible meaning can a word have?), and in phonology (what phonetic features are available to the articulatory and perceptual organs?), as well as in syntax (what computational procedures can the brain implement?). If a child were to find a language inconsistent with principles of UG, she would either not be able to learn it spontaneously, or she would adapt it to these principles (as happens when children develop creole languages from pidgins or when home signs become sign languages)[11].

[11] See Goldin-Meadow (2005) for a detailed discussion of this argument.

As Piatelli-Palmarini (1989) discusses, the instructive theories of the first half of the 20th century in the field of immunology assumed that the synthesis of antibodies could only be done from a set of formless “globulins” willing to receive the “primer” by external antigens. Similarly, the instructive theories of language learning assume that the genesis and development of language is governed solely by general principles of learning, analogous to those we employ to develop specifically human but non-instinctive systems of knowledge, such as playing chess, solving quadratic equations or understanding social institutions or cultural phenomena, such as the baroque or romanticism. The transition from instructive to selective models has been notable in biology in recent decades, both in the field of evolutionary theory and in developmental biology or in immunology. Of course, this fact is not an argument when it comes to language, but it would not be smart not to take it into account, if what we are studying is an attribute of the species, an instinct to learn an art, in Darwin’s formulation (see Pinker 1994).

We have seen so far that the relationship between linguistic theory (biolinguistics in the strict sense) and biology has essentially been one of parallelism (with no little influence of the latter on the former). This fact is a consequence, in my opinion, of two interrelated factors: the crucial importance of methodological naturalism, and the empirical adequacy of the hypothesis that language is a natural object. However, biolinguistics in the broad sense (the grounding of the principles of linguistic theory in more basic disciplines) is a complex and incipiently developing enterprise because it depends not only on the development of linguistic theory, but also on the development of these more basic disciplines.

Several authors (e.g. Di Sciullo & Boeckx 2011) think that “true biolinguistics” (i.e., in a broad sense) really started its development from around the turn of the century, mainly as a consequence of the development of the Minimalist Program (Chomsky 1995). Undoubtedly, the development of the Minimalist Program (MP) is crucial to explain the increase in “biological adequacy” of linguistic theory observed in the last twenty or thirty years, but one cannot ignore the importance in this direction of the decomposition of the faculty of language into distinct components, which may have evolved independently, and may be shared to varying degrees with other species, as proposed in the influential paper by Hauser, Chomsky and Fitch (2002)[12].

4. Minimalism, Evo-Devo and Epigenetics: Beyond “explanatory” adequacy

The biolinguistic theory of language whose history we have been considering in the previous pages has a genuine biological flavor, although it does not deal with tissues, cells or proteins.

We have seen that UG is conceived of as the initial state of the FL[13]. This initial state, essentially common to all human beings, develops, with the growth of the

[12] Although this crucial development of biolinguistic theory may well be considered, likewise, a consequence of the minimalist turn. See Boeckx (2012) for a development of this idea.

[13] As Fitch pointed out, not without some irony, “a huge amount of ink has been shed rejecting the term ‘Universal Grammar’, even by people who accept without question that a biologically-based capacity to acquire

individual and through external linguistic stimulus, into a steady state, that is, into a system of knowledge that allows that person to speak and understand a particular language (or more than one). Following Chomsky (1986), we call this knowledge system I-language (*I* for internal, individual, intensional). In this sense, UG is the "genotype" of the various knowledge systems (I-languages) that develop in people's brains. And this is, as we have seen, the object of study of biolinguistics.

Thus, unlike earlier structuralism and other contemporary functionalist and cognitivist traditions, Chomskyan linguistics introduces a naturalistic perspective in the study of language. But it is clear that there is a considerable distance between, on the one hand, an abstract, theoretical model of the FL and, on the other, the explanation of how it is embodied in the anatomy and physiology of the brain (question 4), or how it came to be the way it is in the human species (question 5), however "biologically inspired" the model may be[14].

As I have indicated, Di Sciullo and Boeckx (2011), among other authors, have argued that one of the crucial factors in the (re)emergence of biolinguistics as a scientific unification program is the minimalist turn staged by Chomskyan linguistics some 30 years ago. It is interesting to note that the essential question of the minimalist program is, in fact, *why language is as it is and not otherwise*, which is still the basic question of science, the real explanatory adequacy.

By the late 1990s, linguistic theory had built a relatively complete and sophisticated theoretical model of the essential structure of the faculty of language (a sketch of an answer to question 1), but this model had difficulties in inspiring answers to the rest of the questions, especially the last two, something unacceptable for a science of language that wishes to integrate with biology and the rest of the natural sciences.

In this model, basically the P&P model, syntax, understood as the generative computational component of human language, produces derivations that interact with interpretation systems (the sensory-motor system and the conceptual-intentional system), which are external to the computational system itself, but internal to the FL. If we return to the example of parameter discussed above, we observe that the universal principle (i.e. that a head takes a complement) can manifest itself in languages in two different ways: head-initial (*eat apples*) / head-final (*apples eat*). It is not by chance that linguistic variation in this case has to do with word order (a specific property of the sensory-motor system, which has to produce a linear sequence of words), and not so much with meaning, which is the same in both expressions. By distinguishing principles from parameters, one is somehow distinguishing between (at least two) distinct components or modules of the faculty of language, and assuming that they may have a different neural

complex language fully is a uniquely-powerful birth-right of any normal human, but no known animal" (Fitch 2009: 288). For a development of this reflection, see Mendívil-Giró (2018).

14 The answers to question 3 (surely the broadest and most complex one) could have a "more biological" treatment when it comes to real-time language processing and production (see Igoa, this volume), but it moves away from this domain when it comes to free language use (Descartes' problem properly), the relationship between language and consciousness, or the use of language for communication (the domain of pragmatics).

implementation, a different developmental trajectory, and a relatively independent evolution.

Thus, the strategy designed by Chomsky to advance beyond "explanatory adequacy" (in the restricted sense indicated) was to "decompose" the faculty of language into various components, and to focus on the one apparently most specific to our species (the recursive syntax that allows "the infinite use of finite means", to use Humboldt's expression often quoted by Chomsky) to formulate a programmatic question: to what extent is this computational system optimally designed to interact with the rest of the components of the mind with which it interacts?

As Di Sciullo and Boeckx point out, the goal was not so much to demonstrate that the computational system is perfect or optimal, but "to see how far the thesis can take us, how productive this mode of investigation can be" (Di Sciullo & Boeckx 2011: 4). In the opinion of these authors, the development of the minimalist program somehow forced the linguists who adopted it to reformulate previous discoveries in terms of basic units, operations and interface conditions. This task can lead to the recognition of entities common to the study of other cognitive abilities (e.g., linear sequences or conceptual representations) and others more specific to language (e.g., syllables or syntactic heads), making the connection with discoveries at more basic levels easier, at least in principle.

The emergence of the MP has an internal source (a consequence of the healthy tendency of all scientific activity to apply Ockham's razor), but it also coincides significantly in time with changes in developmental biology and a better understanding of the relations between genes and phenotypic traits. In addition, the development of this research program also seems to have been relevant to progress in two fields central to the biological explanation of language: comparative cognition studies and language neuroscience.

It is worth recalling now that the developmental biology of the first half of the twentieth century was essentially gene-centered. The geneticist model of development was especially attractive to the Chomskyan approach to language, since it faced a similar problem: how to explain the robustness and homogeneity of language development in an unstable, confusing environment that provides very impoverished evidence about the knowledge systems finally obtained (I-languages). Consequently, the initial models of generative grammar assumed a rich UG, which was thought to be genetically specified, since in the biology of the time "innate" tended to correspond to "genetically encoded". In recent decades, so-called evolutionary developmental biology (Evo-Devo) has transformed evolutionary biology into a much more pluralistic landscape (see Preston and Pigluicci, eds., 2004, Carroll 2005, Longa and Lorenzo 2012). In a gene-centered model, genes are considered as a self-sufficient program that includes information about patterns of structural organization and instructions for the unfolding of structures in time and space. According to the new developmental biology, phenotypic traits cannot be contained or specified in genes (an option that is considered inadequately preformationist). This implies that the notion of "genetic program" as the sole source of information for developmental processes is a distortion of the view of how such processes occur, since it ignores the relevant contribution of other factors and resources situated between genotype and phenotype, and without which the developmental process simply cannot occur (see Benítez-Burraco & Longa 2010).

Furthermore, the MP is also aimed at trying to clarify which aspects of the FL are a consequence of the biological endowment of the species (therefore likely to have evolved and to be genetically or epigenetically encoded) and which aspects of it are a consequence of principles of simplicity, of computational elegance, or of the processes of brain development (which in turn may be a consequence of the evolution of the human brain itself, or of deeper formal or physical principles that govern systems of a given complexity). As Chomsky formulated it, the MP consists of approaching the content of UG "from below", by changing the question of how much to attribute to UG to explain the development of language to the question of how much we can remove from UG and still explain the development of human languages[15].

One way to make the "biologically minimal" character of UG consistent with the complexity of the obtained "phenotypes" (the I-languages spoken by people) is the decomposition of the faculty of language into various components, which could have an independent evolutionary history, as reflected in the influential model of Hauser, Chomsky & Fitch (2002). According to this model of the FL, the key to the "discontinuity" that seems to exist between human language and the communication and cognition systems of other species would not be the improbable biological evolution of a complex language organ, which would not have had time to evolve (much less without "leaving a trace" in other nearby species), but a biologically minimal event that provided the "extra ingredient" to pre-existing conceptual-intentional and sensory-motor systems, endowing the resulting complex (the FL in the broad sense or FLB) with new and unexpected properties. A key idea is then that a possible cognitive discontinuity does not have to imply an improbable biological or evolutionary discontinuity.

Thus, the Faculty of Language in the narrow sense (FLN), would include hypothetically only a recursive computational system (syntax in the narrow sense, perhaps reduced to a single computational operation called *Merge*), which would be essential for the linkage between a conceptual-intentional system and a sensory-motor system to produce a knowledge system with the properties that characterize human language, essentially the main one: the ability to create a potentially infinite number of appropriate sentences (systematic pairings of sound and meaning) from finite means[16].

Later, Chomsky (Chomsky 2007, Berwick and Chomsky 2011) proposed that the relationship between the computational component (Merge) and the sensory-

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[15] "At the time, it seemed that FL must be rich, highly structured, and substantially unique. [...] Throughout the modern history of generative grammar, the problem of determining the character of FL has been approached 'from top down': How much must be attributed to UG to account for language acquisition? The MP seeks to approach the problem 'from bottom up': How little can be attributed to UG while still accounting for the variety of I-languages attained?" (Chomsky 2007: 2, 4).

[16] On the later influence of Merge's theory, see Murphy (this volume) in relation to neurolinguistics, and Fujita (this volume) in relation to language evolution.

motor and conceptual-intentional components is asymmetric, in the sense that the computational system would be adapted for its interaction with the conceptual-intentional system (forming an "internal language of thought"), and that the relationship with the sensorimotor system for the "externalization" of language would be secondary or ancillary. This hypothesis also opens the door to the possibility of increasing what could be called the "evolutionary adequacy" of the FL model by solving some of the classic problems in the application of the adaptive model to the emergence of language as a system of communication (see Berwick and Chomsky 2016 for a full development of this possibility).

Furthermore, this asymmetric model may imply the hypothesis that all (or a good part) of the diversity of human languages resides in the externalization components of language (basically traditional phonology and morphology), while all languages would be underlain by a uniform computational system. This would imply the relocation of traditional parameters at the interface of the "internal language of thought" with the sensory-motor system, an interface that must be formed in the process of language development in each individual (see Mendívil-Giró 2014 for a specific formulation of this hypothesis).

As Boeckx (2012) and Fitch (2009) point out, the decomposition of the FLB in the aforementioned terms has stimulated systematic comparison with cognition and communication systems of other species, allowing us to establish with more reliability which capacities underlying human language are specific or are shared with other organisms, opening a promising field for empirical evaluation of evolutionary scenarios. Besides, the notable success of Evo-Devo has opened new ways of understanding the relationship between genes, and especially the functioning of regulatory genes, showing that there are developmental and evolutionary modules conserved between very distant species and phyla (deep homology). As a consequence of this, it is possible, with regard to the components of language, to compare genes and regulatory patterns of distant species (which in previous moments would not be considered relevant), as is the case of the relations between bird song and the development of control of complex vocalizations in humans. As Piatelli-Palmarini (2013) points out, an important consequence of the modularity of development and the modularity of the mind is that a given module, once created, can remain encapsulated independently of its relations with other internal organs or modules and reappear later in connection with new components.

Along with the notable advance in developmental biology, other technological advances in genetic sequencing may certainly be relevant in answering questions 4 and especially 5. Thus, more recently, sequencing technology and computational tools made possible what seemed impossible a short time ago: the sequencing of the Neanderthal genome. The possibility of comparing the genome of this extinct species with that of current humans could be decisive in resolving some traditional controversies among researchers of the evolution of language and cognition. Of course, this implies that we have a solid knowledge of which genes are directly related to language in our species, something that is far from true (see Benítez-Burraco 2012 for a complete synthesis of studies on this matter).

The famous case of the *FOXP2* gene could be an exception (see Piattelli-Palmarini, & Uriagereka 2011 for a review). This gene was identified due to a mutation that caused individuals who carried it to suffer from developmental dyspraxia specific to oro-motor control, which leads to a severe developmental speech disorder, while preserving the rest of the linguistic abilities (Pääbo 2014). *FOXP2* is a regulatory gene that is connected to a broad network of genes with effects on various tissues in the body. According to Enard *et al.* (2002), *FOXP2* exists in a human-specific allele, and it codes a protein that differs from that of chimpanzees, which do not have language. However, as Berwick and Chomsky (2011) point out, despite what was initially believed, *FOXP2* seems to be involved primarily in the sensory-motor component (the externalizing component of language), rather than in the "central" components responsible for syntax and semantics. Even so, the evaluation of that sequence in the Neanderthal genome showed that this gene codes for the same protein as in our species, which suggests that the relevant mutation occurred after our separation from chimpanzees (about 6 million years ago), but before the bifurcation between modern Humans and Neanderthals (about 500,000 years ago). Of course, we know from new developmental biology that no single gene can be responsible for the human ability to speak, but the fact that the gene is identical in both species seems to suggest that Neanderthals had an ability to speak similar to ours, although there is no guarantee that they had language in the narrow sense (rather it seems unlikely from the paleontological record, as argued in Tattersal 2016, although the issue is, of course, controversial).

Furthermore, the decomposition of the various components of the FL may also have had some influence on the progress in recent decades in understanding the relationship between language and the brain (question 4). As David Poeppel has pointed out, the crucial question is how the primitive units of linguistic analysis (e.g. distinctive features, morphemes or categories) and the primitive units of neurobiological analysis (e.g. dendrites, cortical columns or long-term potentials) can be related and, above all, how to resolve the probable discrepancy in the "granularity" of the analysis in both fields (Poeppel 2005). The minimalist version of linguistic theory is perhaps the most appropriate cognitive model to be able to delve deeper into this task of explanatory matching with the neurobiological level of implementation in the future.

Although still far from that objective, the neurolinguistic research (inspired by the generative model of syntax) by Angela Friederici and her team (see Friederici 2017 for a synthesis) has shown with extensive experimentation that Broca's area does seem to be selectively involved in the processing of hierarchical syntax (Friederici 2011), something consistent with the independent discovery that Broca's area (B44 and 45) is six times larger in humans than in chimpanzees (when the human brain is about three times larger than that of our close relatives), and that it is in humans much more connected, via dorsal pathway, to areas of the temporal and parietal cortex (Fitch 2014). Fitch (2014) has suggested that perhaps Broca's area plays a computational role as a kind of memory stack for processing grammars of a certain complexity. In any case, it seems to be true today, as it was at the beginning of the biolinguistics enterprise, that "despite huge progress, at a basic level we still do not understand how brains generate minds. This is as true of a dog's brain as for a human's, and it is true of very basic aspects of cognition, such as vision and motor control, along with language" (Fitch 2009: 285).

However, the relatively modest progress in this direction (see Martínez-Ferreiro, this volume) still implies, as Fitch also points out, that we need models at the computational level that are explicit and whose primitives are defined at a fine enough grain that algorithmic and implementational approaches to their solution can be feasible. More specifically, he points out that "we need a list of computations that linguistic theorists deem indispensable to solve their particular problem (e.g., in phonology, syntax, or semantics)" (Fitch 2009: 298). As the same author indicates, unlike what happens with other organs, in which it is possible to establish relations between their structure and functions, the cortical circuits supposedly involved in language have the same types of cells and are connected with subcortical systems in the same way that circuits not (apparently) related to language are. Likewise, the developmental processes that form both seem to be the same, so we can expect that the bulk of the aspects of the neural implementation of language will be based on relatively general principles of the development and functioning of the mammalian brain phylogenetically close to us. For this reason, Fitch concludes, "I see the algorithmic specification of the various components of language, based upon explicitly stated computational primitives and algorithm models, as a crucial missing link in our attempts to build the larger bridge between mind and brain". (Fitch 2009: 300).

Echoing the history of the reduction of chemistry in physics (which involved a revolution in physics with chemistry virtually intact), Piatelli-Palmarini (2013: 18) has suggested that in the case of language, as in that of other cognitive systems in general, a profound revolution in neuroscience will be necessary to answer question 4, which will inevitably delay, perhaps forever, an answer to question 5. Thus, if progress in paleogenetics prompts us to be optimistic, the limitations in relating the anatomy and physiology of the brain to meaning, ideas, and intentions do not seem to rule out Lewontin's pessimistic prediction: "We know essentially nothing about the evolution of our cognitive capabilities, and there is a strong possibility that we will never know much about it. [...] It might be interesting to know how cognition (whatever that is) arose and spread and changed, but we cannot know. Tough luck" (Lewontin 1998: 109, 130).

5. Final remarks on the unification of Linguistics and Biology

As Trettenbrein observes in assessing the current state of development of Lenneberg's (1967) ideas about the biological bases of language, "despite all technological advancements and progress in the study of language it is still not clear whether the prospect of such a unified science, though incredibly attractive, is realistic even in the very long run—be it for biolinguistics or cognitive science in general" (Trettenbrein 2017: 25).

The initial model of generative grammar sought descriptive adequacy (accounting for the "deep structure" of linguistic expressions). The P&P model aspired to what was technically called "explanatory adequacy" (accounting for language acquisition) without losing a bit of descriptive adequacy, but it did so by postulating a rich and innate linguistic component excessively specific (as opposed to other cognitive abilities) and excessively human (with respect to the cognitive abilities of other species). The type of adequacy pursued in the MP (beyond "explanatory" adequacy) has been characterized as "neurological adequacy," "biological adequacy," or even "evolutionary adequacy". And, indeed, the MP, if it is able to maintain descriptive adequacy, represents progress in that direction, in the sense that a reduced and simpler innate component is undoubtedly less stipulative, more biologically plausible, and easier to reconcile with credible stories about its evolution. Besides, the relevance that the factors of elegance and computational economy gain in this model in relation to the architecture of language and its production and processing would also allow us to speak of an increase in "computational adequacy" (and even in "mathematical adequacy", in a general sense), which further suggests real progress in the common and central enterprise of science, which is none other than that of unification.

As the physicist Murray Gell-Mann, also a Nobel laureate, explained, quantum electrodynamics allows chemistry to be reduced to physics, but to be able to derive, at least in theory, the laws of chemistry, it is necessary to introduce additional information into the equations of particle physics. Without these considerations, the notion of reduction is incomplete (Gell-Mann 1984). This additional information that must be added is crucial to not confuse scientific reduction with simplification. As Gell-Mann points out, a science belonging to a certain level encompasses the laws of another less fundamental science, located at a higher level, but the latter, being special, requires additional information to complete the lower level laws. Only a sophisticated and empirically correct linguistic theory (biolinguistics in the narrow sense) can provide the "additional information" that biolinguistics in the broad sense needs to have any explanatory value. As Gell-Mann goes on to say, "at each level there are laws to discover, important in their own right", so that "the enterprise of science involves investigating those laws at all levels, while also working, from the top down and from the bottom up, to build staircases between them" (Gell-Mann 1994: 112). This is the role to which biolinguistics is called in the area of science that studies human nature.

Long before the emergence of biolinguistics, Darwin wrote in his autobiography (Darwin 1887) that the study of the baboon brain would do much more for the understanding of the human mind than Locke's essay. It seems that time is proving him right, but this should not invite us to confuse the unification between sciences with simplification, because simplification is not explanatory.

References

Balari, S. 2012. Up the Cudgels for Lenneberg. In C. Boeckx, M.C. Horno & J.L. Mendívil-Giró (eds.): *Language, from a Biological point of view*, Newcastle: Cambridge Scholars, pp. 208-214.

Benítez-Burraco, A. 2012. The "Language Genes". In C. Boeckx, M.C. Horno & J.L. Mendívil-Giró (eds.): *Language, from a Biological point of view*, Newcastle: Cambridge Scholars, pp.: 215-262.

Benítez-Burraco, A. & V.M. Longa 2010. Evo-Devo –Of Course, But Which One? Some Comments on Chomsky's Analogies between the Biolinguistic Approach and Evo-Devo. *Biolinguistics,* 4, 308–323.

Berwick, R.C. & N. Chomsky 2011. The Biolinguistic Program: The Current State of its Development. In A.M. Di Sciullo & C. Boeckx (eds.): *The Biolinguistic Enterprise. New Perspectives on the Evolution and Nature of the Human Language Faculty*. Oxford: Oxford University Press, pp. 19-41.

Berwick, R.C. & N. Chomsky 2016. *Why Only Us: Language and Evolution.* Cambridge, MA: MIT Press.

Boeckx. C. 2012. The I-Language Mosaic. In C. Boeckx, M.C. Horno & J.L. Mendívil-Giró (eds.): *Language, from a Biological point of view*, Newcastle: Cambridge Scholars, pp. 23-51.

Boeckx, C. & K.K. Grohmann. 2007. The Biolinguistics *manifesto*. *Biolinguistics*, 1, 1–8.

Carroll, S.B. 2005. *Endless Forms Most Beautiful*. New York: W.W. Norton.

Chomsky, N. 1955/1975. *The Logical Structure of Linguistic Theory*. New York: Plenum Press.

Chomsky, N. 1957. *Syntactic Structures*. The Hague: Mouton

Chomsky, N. 1959. A review of B. F. Skinner's Verbal Behavior. *Language*, 35(1), 26–58.

Chomsky, N. 1965. *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.

Chomsky, N. 1966. *Cartesian Linguistics*. New York: Harper & Row.

Chomsky, N. 1980. *Rules and Representations*. Oxford: Blackwell.

Chomsky, N. 1981. *Lectures on Government and Binding*. Dordrecht: Foris.

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

Chomsky, N. 1988. *Language and problems of knowledge. The Managua Lectures*. Cambridge, MA: The MIT Press.

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

Chomsky, N. 2000. *New Horizons in the Study of Language and Mind*. Cambridge: Cambridge University Press.

Chomsky, N. 2004. Language and Mind: Current Thoughts on Ancient Problems. In Jenkins, L. (ed.). *Variation and Universals in Biolinguistics*. Amsterdam: Elsevier, pp. 379-405.

Chomsky, N. 2007. Approaching UG from below. In Uli Sauerland & Hans-Martin Gärtner (eds.), *Interfaces + recursion = language? Chomsky's minimalism and the view from semantics*. Berlin: Mouton de Gruyter , 1–30.

Chomsky, N. & H. Lasnik 1993. The Theory of Principles and Parameters. In J. Jacobs, A. von Stechow, W. Sternefeld & T. Vennemann (eds.): *Syntax. An International Handbook of Contemporary Research*. Berlin: Walter de Gruyter, 506–569.

Darwin, C. 1887/1958. *The Autobiography of Charles Darwin (Edited by Nora Barlow)*, London: Collins.

Di Sciullo & C. Boeckx 2011. Introduction: Contours of the Biolinguistic Research Agenda. In A.M. DiSciullo & C. Boeckx (eds.): *The Biolinguistic Enterprise. New Perspectives on the Evolution and Nature of the Human Language Faculty*. Oxford: Oxford University Press, pp. 1-16.

Enard, W., M. Przeworski, S.E. Fisher, C.S. L. Lai, V. Wiebe, T. Kitano, A.P. Monaco & S. Pääbo. 2002. Molecular evolution of FOXP2, a gene involved in speech and language. *Nature,* 418, 869–872.

Everaert, M.B.H., M.A.C. Huybregts, N. Chomsky, R.C. Berwick & J.J. Bolhuis. 2015. Structures, Not Strings: Linguistics as Part of the Cognitive Sciences. *Trends in Cognitive Sciences,* 19(12), 729–743.

Feynman, R. (1963) The Relation of Physics to Other Sciences, In *The Feynman Lectures on Physics* [www.feynmanlectures.caltech.edu/I_03.html]

Fitch, W.T. 2009. Prolegomena to a Future Science of Biolinguistics. *Biolinguistics,* 3, 283–320.

Fitch, W.T. 2014. Toward a Computational Framework for Cognitive Biology: Unifying approaches from cognitive neuroscience and comparative cognition. *Physics of Life Reviews* 11(3), 329–364.

Fitch, W.T. 2017. What Would Lenneberg Think? Biolinguistics in the Third Millennium. *Biolinguistics*, 11/SI: 445-461.

Friederici, A.D. 2011. The Brain Basis of Language Processing: From Structure to Function. *Physiological Reviews* 91(4), 1357–1392.

Friederici, A.D. 2017. *Language in our Brain: The Origins of a Uniquely Human Capacity*. Cambridge, MA: MIT Press.

Gell-Mann, M. 1994. *The Quark and the Jaguar. Adventures in the Simple and the Complex*, New York: W.H. Freeman and Company.

Goldin-Meadow, S. 2005. *The Resilience of Language*. New York: Psychology Press.

Hauser, M.D., N. Chomsky & W.T. Fitch 2002. The Faculty of Language: What Is It, Who Has It, and How It Evolve? *Science,* 298, 1569-1579.

Jackendoff, R. 1994. *Patterns in the Mind: Language and Human Nature*. New York: Basic Book.

Jenkins, L. 2000. *Biolinguistics. Exploring the Biology of Language*. Cambridge: Cambridge University Press.

Jenkins, L. 2013. Biolinguistics: A historical perspective. In C. Boeckx & K. Grohmann (eds.): *The Cambridge Handbook of Biolinguistics*. Cambridge: Cambridge University Press, pp. 4-11.

Jerne, N.K. 1985. The Generative Grammar of the Immune System (Nobel Lecture). *Science*, 229, 1057-1059.

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

Lewontin, R. 1998. The evolution of cognition: Questions we will never answer. In D. Scarborough & S. Sternberg (eds.), *Methods, Models, and Conceptual Issues: An Invitation to Cognitive Science*, Cambridge, MA: The MIT Press, pp. 108-132.

Lobina, D.J. 2014. What linguists are talking about when talking about... *Language Sciences,* 45, 56–70.

Longa, V.M. & G. Lorenzo. 2012. Theoretical Linguistics meets development. Explaining FL from an epigeneticist point of view. In Boeckx, M.C. Horno & J.L. Mendívil-Giró (eds.): *Language, from a Biological point of view*, Newcastle: Cambridge Scholars, pp.: 52-84.

Martins, P.T. & C. Boeckx. 2016. What we talk about when we talk about biolinguistics. *Linguistics Vanguard* 2(1). doi:10.1515/lingvan-2016-0007.

McGilvray, J. 2013. The philosophical foundations of biolinguistics. In C. Boeckx & K. Grohmann (eds.): *The Cambridge Handbook of Biolinguistics*. Cambridge: Cambridge University Press, pp. 22-46.

Mendívil-Giró, J.L. 2014. What are languages? A Biolinguistic perspective. *Open Linguistics* 1, 71–95.
Mendívil-Giró, J.L. 2018. Is Universal Grammar ready for retirement? A short review of a longstanding misinterpretation. *Journal of Linguistics*, 54(4), 859-888.
Pääbo, S. 2014. The human condition—A molecular approach. *Cell,* 157, 216–226.
Piatelli-Palmarini, M. 1989. Evolution, Selection and Cognition: from 'learning' to Parameter Setting in Biology and in the Study of Language. *Cognition*, 31, 1-44.
Piatelli-Palmarini, M. 2013. Biolinguistics yesterday, today, and tomorrow. In C. Boeckx & K. Grohmann (eds.), *The Cambridge Handbook of Biolinguistics*. Cambridge: Cambridge University Press, pp. 12-21.
Piatelli-Palmarini, M. 2017. From Zero to Fifty: Considerations on Eric Lenneberg's *Biological Foundations of Language* and Updates. *Biolinguistics*, 11/SI: 423-444.
Piattelli-Palmarini, M. & J. Uriagereka. 2011. A geneticist's dream, a linguist's nightmare: The case of *FOXP2*. In A.M. Di Sciullo & C. Boeckx (Eds.): *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*. Oxford: Oxford University Press, pp. 100–125.
Pinker, S. 1994. *The Language Instinct. How the Mind Creates Language*. Cambridge, MA: The MIT Press.
Poeppel, D. 2012. "The *maps* problem and the *mapping* problem: Two challenges for a cognitive neuroscience of speech and language", *Cognitive Neurophychology*, 29(1-2), 34-55.
Preston, K. & M. Pigliucci (eds.) 2004. *Phenotypic Integration: Studying the Ecology and Evolution of Complex Phenotypes*, Oxford: Oxford University Press.
Tattersall, I. 2016. How can we detect when language emerged? *Psychonomic Bulletin & Review* 24(1), 64–7.
Trettenbrein, P. 2017. 50 Years Later: A Conversation about the Biological Study of Language with Noam Chomsky. *Biolinguistics* 11/SI: 487-499.
Weinberg, S. 1992. *Dreams of a final theory*. New York: Vintage.