The Faculty of Language [*]

A biological object, a window into the mind, and a bridge across disciplines

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1. The Study of Language: Some Preliminary Remarks

There are many ways to study language. One is to concentrate on what we may call "production" (what we say, write, etc.), which plays a key role in human communcation. And we can also do it by trying to characterizing what makes that production possible: An knowledge internal to the mind / brain of the speakers that yields that production.

There has been—and there is—controversy on whether that knowledge is learnt (through conscious strategies, memorization, etc.) or acquired unconsciously (through the exposition to language of a child within a linguistic community). There is considerable evidence for the latter conclusion, and for the hypothesis that the faculty of language (and its actual manifestations, natural languages) is an exclusively human cognitive capacity whose appearance is relatively recent on the evolutionary timescale (between 120.000 and 200.000 years, it seems; cf. Bolhuis et al. 2014, Berwick & Chomsky 2016, Chomsky 2017b).

Such line of thought goes back to Descartes' observation, in the *Discours on Method*, that "there are no men so dull-witted or stupid […] that they are incapable of arranging various words together and forming an utterance from them in order to make their thoughts understood; whereas there is no other animal, however perfect and well endowed it may be, that can do the same." *Universal Grammar* (UG) is the label that has been used to design this crucial difference (having or not a language-ready brain), in terms of cognitive capacity, between "us and them."

Research on comparative cognition carried out for decades has backed up what Descartes pointed out: Only humans have a MENTAL GRAMMAR, also called I-LANGUAGE, where the "I" stands for *internal*, *intensional* and *individual* (cf.

[*] This is a modified version of Chomsky et al. (2019). For readers that want to deepen into these matters, we recommend the volumes Bosque & Gutiérrez-Rexach (2009) and Gallego (2016, 2020), which offer a more comprehensive and detailed discussion. We thank Ignacio Bosque, Elena Ciutescu, Edita Gutiérrez, Lourdes Domenech, and Francesc Reina for comments to a previous version of this paper.

Chomsky 1986).[1] The notion of I-language refers to a *knowledge* that allows speakers to generate and understand a potentially unbounded set of expressions.[2, 3]

GENERATIVE GRAMMAR is the study of UG. That is, of the linguistic capacity inasmuch as a component of human cognition. From that point of view, the study of language should focus on I-Language (the internal, unconscious knowledge of a language), even though the main way to do it is through E-Language (the actual manifestations of such knwoledge). In general, the investigation of an I-Language has been carried out by acceptability judgments with minimal pairs like that in (1):

(1) The evidence was {recovered / *arrived}

The contrast in (1) is not taught in High Schools, nor in most (if not all) grammar textbooks. However, it is obvious to all speaker of Spanish, and it tells us that the presence of the unaccusative verb *arrive* in a passive structure violates some principle.[4]

Apart from introspection, which is indiviudal (as we expect, as it is part of an I-Language) and can be resorted to very easily, in recen years neurological and psychological experimental techniques have been developed that allow us to observe how language manifests in the brain (cf. Laka 2015, Berwick et al. 2013; Nelson et al. 2017; Friederici et al. 2017).

The same can be said from language acquisition studies, which have shown that children produce, spontaneously (with no external stimuli or pressures), expressions with properties of languages different from the ones acquired by the environment. Crucially, expressions that deviate from general grammatical principles (of UG; Crain & Thornton 1998, 2012, Crain et al. 2017), like those having to do with structure dependence, which we will review in section 5, are never produced.[5]

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[1] It also means *intensional*, but we put aside this notion to simplify the exposition.

[2] This knowledge has also received the name of COMPETENCE, and was introduced as a technical term to avoid (largely philosophical) controversies about the very concept of 'knowledge.' We avoid the use of this label, as it is currently related, especially in the education domain, with the execution of a skill (cf. Bosque & Gallego 2018).

[3] In the literature, I-LANGUAGE is opposed to E-LANGUAGE (where the "E" stands for *externalized* and *extensional*), "a collection of actions, or utterances, or linguistic forms (words, sentences) paired with meanings" (Chomsky 1986:19; cf. also Chomsky 2012a, 2017a). Despite its widespread use, it is not immediately obvious which expressions belong to so-called E-Language, so we will not make us of this notion here.

[4] Unaccusative verbs are intransitive verbs that express a change of state or location. Their only argument is not interpreted as an agent (it is a /PACIENT/ o /THEME/) and since they cannot assign accusative (and, thereore, cannot have a Direct Object), they rule out passives. For a more complete and accessible characterization of these verbs, we refer the reader to Bosque & Gutiérrez-Rexach (2008), Gallego (2016), as well as RAE-ASALE (2009).

[5] Similar evidence is provided by spontaneous creation of sign languages by deaf children that have not had linguistic input (cf. Feldman et al. 1978; Kegl. et al. 1999; Sandler & Lillo-Martin 2006).

This point takes us directly to one of the main arguments in favor of the biological perspective of the study of language: The POVERTY OF STIMULUS (PoS; cf. Chomsky 2012b and Berwick et al. 2011 for an overview). PoS is concerned with the observation that environmental stimuli do not determine the development of organisms; for the most part, they do not come even close—e.g., How does the nutritional input into an embryo determine whether it will grow into a cat or a monkey?). This can be seen in throughout biology (e.g., insect and vertebrate genomes give rise to different visual systems, independent of external stimuli), but also in language acquisition.

A clear example has to do with the difference between linear order and hierarchichal order, to which we return later. Every linguistic expression uttered or written is a unidimensional object in which words appear in a linear adjacency relationship—that is, one after the other. But a linguistic expression is also a complex n-dimensional object in virtue of hierarchichal relations that may or may not match a given linear order. For instance, the sentences in (2) and (3), although they display a different linear order (the object NP is to the right of the verb in (2) and to its left in (3)), have the same hierarchichal order:

(2) John has read **the book** [English]
John auxiliar read the book
'John has read the book'

(3) Jonek **liburua** irakurri du [Basque]
Jon book read auxiliar
'Jon has read the book'

Linearly, the V – DO dependency of (2) and (3) is the opposite, but the meaning is the same. This tells us that the syntactic structure must be the same, one in which V and DO form an abstract unit (a phrase) that leaves the subject aside: roughly, [Sub [V DO]].[6] But, of course, for that we have to assume that the syntax that is relevant for interpretation is encoded in terms of hierarchy and does not care about linear order, an idea that is questioned by many still nowadays—others have not even heard of it, as it is not usually found.

In this paper we provide our vision of some of the aspects that should be taken into account for the study of language from a biological point of view. Many of them, we believe, could be naturally incorporated into Secondary Education levels. That would allow teenagers to study language not only as a means of communication or artistic creation (which justifies, at least in some countries, its intimate relation with literary and instrumental approaches), but also as a *window to the human mind* and as a *bridge between Humanities and Sciences*.

[6] In this type of structures, linear order is irrelevant—both *Juan* and *the book* can appear to the right of left of the verb. What matters are the hierarchical relations, which pressupose a combinatorial timing: that is, whether the verb and the book merged first, or whether the verb and John did. It is useful to think about these objects as if they were Calder mobiles, without their pieces not having a predetermined linear order.

Discussion is divided as follows: section 2 introduces the fundamental properties of human language, which are related to the operations relevant for the formation of syntactic structures and the Case and agreement dependencies (which determine syntactic functions); in section 3 we focus on the relations that syntax holds with the thought and externalization systems; section 4 discusses some optimal properties of language and the way in which they can make us establish connections with scientific disciplines; finally, section 5 summarizes the main concusions.

2. Basic Properties of Language

Since Aristotle at least, language is defined as the union of "sound with meaning." Before testing this definition, we must ask ourselves what kind of system an I-Language is. There are two properties that we consider non-negotiable and that every theory that wants to account for the traits of the human linguistic capacity must assume: (i) DISCRETE INFINITY and (ii) DISPLACEMENT. Lexical units (words) are combined to create syntactic objects (SOs; also so-called "phrases") of potentially unbounded lenght, as in *Someone said that you think that Mary believes that…*, and some of its components can appear in a position different from the one they are interpreted, as in *What do you think that Mary ate __* ?, where *What* is 'displaced' respect to the position in which it is interpreted as argument of *eat* (signaled with a low dash: __).

The first non-negotiable property takes us to the traditional observation that there is "no longest sentence," just like there is no "largest number." Galileo described this property with surprise in his *Dialogue*, when admitting that language allows to communicate "[one's] most secret thoughts to any other person … with no greater difficulty than the various collocations of twenty four little characters upon a paper," something he described as the greatest of human inventions (Chomsky 1966 [2009]:125). Thus, in the same manner that the successor function in (4) yields all the natural numbers (the set $\mathbb{N}$ in (5)), human language yields sequences like that in (6). The question is what function (operation) allows us to do that.

(4) $S(n) = n + 1$

(5) $\mathbb{N} = \{0, 1, 2, 3, 4, \ldots\}$

(6) Don Quijote thinks that Sancho believes that Dulcinea said that …

The second non-negotiable property can be illustrated with a vast number of examples from any language. The classical example is the active-passive alternation in (7):

(7) a. Arthur removed the sword from the stone
b. The sword was removed from the stone by Arthur

The Noun Phrase (NP) *the sword* is interpreted as a /PATIENT/ of the action of the verb *remove* in both (7a) and (7b), but it appears in different positions. In a theory in

which the interpretation of a phrase is determined by the position it occupies, we must conclude that the sentences (7a) and (7b) are, at the relevant level of analysis, identical.[7] That is to say, that the passive version (7b) is a transformed version of the active sentence (7a), which can be considered a previous stage. In fact, it is possible for the NP to occupy the very "object position (semantic object)" (to the right of the verb) both in actives and passives in Spanish, as (8) shows:

(8) a. Arthur [$_{VP}$ removed *the sword*] from the stone
b. Was [$_{VP}$ removed *the sword*] from the stone by Arthur

To explain the symmetry and asymmetry in (7) (*the sword* is interpreted in the same way in both sentences, but it appears in different positions), we need a computational system that can, firstly, generate (8b) and, secondly, displace the NP to the position it occupies in (7b). That is to say, we need to reflect in a formal way what happens inside our heads when we generate these sentences and why it happens that way: why the interpretation of (7a) and (7b) is identical, why the NP *the sword* appears in one position or in another, etc.

We therefore need a simple compositional operation, call it MERGE, which applies to two objects, α and β, to yield a third one, K, which we can representa as [$_K$ α, β].[8] With this basic tool, plus a lexicon (a finite set of units) we can build any syntactic structure of any language.

Let us imagine that we have a protable lexicon, like that in (9), and the operation MERGE, defined as in (10):

(9) LEXICON = {Ulysses, horse, build, a}

(10) MERGE (α, β) = [$_K$ α, β]

From here, we can generate the sentence *Ulysses built a horse* through the successive application of (10) to the units in (9), as (11) shows:

(11) a. MERGE (a, horse) = [$_K$ a horse]
b. MERGE (built, K) = [$_M$ built [$_K$ a horse]]
c. MERGE (Ulysses, M) = [$_L$ Ulysses [$_M$ built [$_K$ a horse]]]

[7] We are assuming that there is a relationship between the position in which an NP is generated (within a structure) and the way in which It is interpreted. To be more specific: we adopt the idea that all NPs that are interpreted as a patient are first merged in a sister position to the verb. That is the position of DOs of transitive verbs (*I sent <u>the presents</u>*) and subjects of unaccusative verbs (*<u>The presents</u> arrived*).

[8] The object [$_K$ α, β] is equivalent to {α, β}, in set theory notation. We put aside this formulation for expository reasons. A crucial aspect of set-theoretic objects is that they abstract from linear order (in Set Theory, {α, β} = {β, α}). This is a welcome conclusion, as we will see later when discussing structure dependency (in section 4).

Interestingly, with the units in (9) we can also built (12), where the NP *a horse* is displaced (focus-fronted) to the left.

(12) A HORSE Ulysses built!

The meaning of (12) is that of *Ulysses built a horse* plus 'something else.' It makes sense to think that that 'something else' (emphasis, focus, etc.) comes from the displacement of the NP to the sentence initial position. It is not necessary to postulate an additional operation to account for such displacement: If we take the definition in (10) seriously, then we only have to merge L and K to get (13). That is all we need. In the representation provided in (13) we see that the NP *a horse* appears in two positions: the initial one (where the NP is interpreted as /PATIENT/ of the verb *build*) and the final one (in bold, where it is interpreted as the focus of the sentence).

(13) MERGE (K, L) =
[$_{L'}$ **[$_{K}$ a, horse]**,[$_{L}$ Ulysses, [$_{M}$ built, [$_{K}$ a, horse]]]]

Obviously, we do not pronounce the same NP twice when we speak, so there must be a phonetic mechanism that deletes one of the copies—similarly to what happens in ellipsis cases, such as in *Someone ate rice, but nobody did ∅ pasta*, where the verb *buy* is supressed in the adversative sentence, in which the symbol ∅ indicates the position occupied by the tacit/silent verb. This is a trait of optimal computation: It ensures a potentially huge saving of internal computation and articulation, as the displaced element can be arbitrarily complex. Typically, this mechanism erases the most embedded copy in the structure (the innermost), something that also happens in the passive, interrogative and relative clauses in (14)—where, again, we signal the copy that is pronounced in bold, and the position where it is semantically interpreted through a low dash.

(14) a. **The horse** was built ___ by Ulysses
b. **What** built Ulysses ___ ?
c. The horse **with which** Ulysses entered Troy ___

As can be seen, the recursive application of MERGE provides both discrete infinity and displacement. The only relevant difference has to do with the elements it operates with: If the units combined come from the lexicon (or have been assembled in independent workspaces, thus qualifying as phrases), we have EXTERNAL MERGE (the two units combined are independent from one another, so $\alpha \neq \beta$); if the units combined have already been manipulated, we have INTERNAL MERGE (one of the units combined comes from within the other, so $\neg\alpha \neq \beta$); in (13), for example, K is part of L).

INTERNAL MERGE (or displacement / movement) can be local (short-distance), as in the examples in (14), but it can also relate two positions far from each other (long-distance), as in those in (15).

(15) a. **A horse** seems to have been seen __ entering Troy

b. **What** seems to have been seen __ entering Troy?
c. A horse **with which** it seems that Ulysses entered Troy __

If what we have said so far is on track, there are various copies of the NPs in bold. At least, there must be another copy of each NP in the position signaled with ___ , for that is the only way to ensure that the thematic role is, in all the cases, the same that *Ulysses* has in *Ulysses built a horse*: that of agent of the action of *build*. The existence of two copies would account for the interpretive duality of the elements that undergo displacement: one encodes the thematic semantics[9] (analogous to that in predicate logic) and the other the semantics related to discourse properties and operator-variable structures (which determine whether a structure is a question, an order, etc.).

It is important to insist that MERGE does not create lineal objects (lists), but hierarchical ones, created 'from inside out,' not 'from left to right.' Let us give an example that will illustrate this difference more clearly. Take the example in (16):

(16) Fish fish fish

This example is interesting, as it is ambiguous. More specifically, (16) can be interpreted as a list or as a phrase (a hierarchical object). We indicate both readings in (17):

(17) ONLY RELEVANT IN SPANISH, WHERE THE READINGS HAVE A DIFFERENT SYNTAX

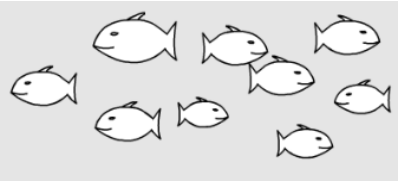
Since the interpretation is different, the syntactic analysis must be different too. A wat to capture the asymmetry above is shown in the representations in (18):

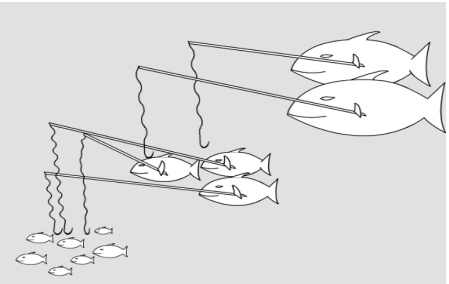
(18) a. $[_1$ Fish] $[_2$ fish] $[_3$ fish]
b. $[_4$ $[_1$ Fish]] $[_5$ $[_2$ fish] $[_3$ fish]]

As can be seen, there is a correlation between the structure being more complex (in (18b)) and the interpretation being more complex too. Therefore, having 'more structure' entails 'more meaning.' A graphic way to see the difference in (XX) is offered in the following pictures:

(19) a. $[_1$ Fish] $[_2$ Fish] $[_3$ Fish] b. $[_4$ $[_1$ Fish]] $[_5$ $[_2$ Fish] $[_3$ Fish]]

[9] By "thematic semantics" we understand the part of semantics that accounts for the interpretation that predicate assign to their arguments—for instance, determining whether the NP *the student* is interpreted as an agent (in *The student protested*) or a patient (in The student was warned).





[from Freidin 2012: 8]

If one goes beyond the obvious distinction in (19), it seems key to us to underscore the importance of the fact that, when we do syntactic analysis (at any educational level), we must see that there is a direct relation between analyzing something and capturing its meaning—not just drawing a tree (or whatever relevant representation). In fact, and departing from common practice, analyzing should be a synonymous to understanding.

Along with MERGE, do we need another operation to build SOs? All the agreement phenomena in natural languages suggest that there is an operation that relates the features of different elements of an expression. We can call AGREE such operation. Recent work picks up the idea (traditional, incidentally) that AGREE is an asymmetric process, in the sense that one of the two elements that participate in it triggers the process. The paradigmatic example comes from number and person agreement established between an inflected verb and an NP. In (20), the verb *defeat* agrees with the NP *Achilles*, and not the other way around, which makes us consider that it is the former that triggers the operation.

(20) Achilles defeated Hector

This way to conceive of agreement makes sense, as gender, number and person on verbs (so-called φ-features) are not interpretable, whereas those of nouns are. That φ-features on verbs are not interpreted is a fact—there is, therefore, no possible discussion. The plural morpheme of the N *libros* (Eng. 'books') tells us that the cardinality of elements x, if x = book, is more than one. The same does not hold, for instance, in *cantan* (Eng. 'they sing'), where the final *n* does not indicate that the singing event occurs more than once. What it indicates is that there is more than one individual that carries out of the singing action. It is odd for language to be designed that way, with morphology that appears on elements in which it is not interpreted. Traditional grammar spoke, in such cases, of "agreeing plurals." It looks like an imperfection, in the sense that there is an element there even though it cannot be interpreted, it has no meaning. And notice that in thousands of years of linguistic investigation (even today for many, we believe), none of these things were considered imperfections—or issues worth looking into. Such questions only arise when language begins to be studied as part of the sciences.

If we suppose that valuation is a necessary process for the good formation of a structure like (20), we can say that the verb works as a PROBE that seeks a GOAL to value its features.

Another apparent imperfection concerns so-called straight (or structural) Cases, nominative and accusative, which correspond to the syntactic functions of Subject and Direct Object (DO) respectively. In languages like Latin, nominative and accusative were expressed phonetically, as can be seen in (17), where the desinencies –M and –US indicate that type of information.

(21) Serv -US puella-M amat [Latin]
slave-nom girl -acu loves
'The slave loves the girl'

Even though they are not manifested phonetically in all languags, it is necessary to postulate the existence of Cases to explain the distribution of NPs in natural languages. [10] What is striking about this morphology is that, like φ-features of verbs, it is not interpreted. A notable example, and very well-known, is the active-passive alternation, but we can show the same in structures like (22), where the interpretation of the NP *Arthur* is identical in both cases: in both (22a) and (22b) *Arthur* is the /AGENT/ of the action, but it bears different syntactic functions, Subject and DO.

(22) a. Nobody saw that $\text{Arthur}_{\text{NOM}}$ removed the sword
b. Nobody saw $\text{Arthur}_{\text{ACU}}$ remove the sword

We have, in sum, two imperfections: the φ-features on verbs and the structural Cases (nominative and accusative). An ideal scenario would be one in which both imperfections were related; that is to say, one where agreement and syntactic functions were the two sides of the same coin. A mechanism that suffices to account for this is AGREE. Suppose that that φ-features of verbs assign nominative case to the subject NP, more or less as indicated in (23) and (24). In these structures we are assuming that a sentences has at least two layers: a lexical layer (the VP) that takes care of capturing semantic dependencies (wheather an NP is interpreted as an agent, a patient or a goal) and a grammatical one, embodied in "INF" (for "inflection"), which assigns syntactic functions (whether an NP is a subject or a DO):

(23) [INF[person: __] [number: __] [SV Brutus[person: 3] [number: SG] [case: __] stabbed Caesar]]

(24) [INF[person: 3] [number: SG] [SV Brutus[person: 3] [number: SG] [case: NOM] stabbed Caesar]]

[10] As Jean-Roger Vergnaud showed in 1977, in a letter that took traditional ideas with crucial consequences for the development of contemporary linguistic theory

In (23) and (24) we have representes the INF node before and after valuation. As we can see, the φ-features of that element match those of the closest NP: Brutus. In so doing, person and number of FLEX are valued and the NP receives nominative Case.

Such data as these (and more generally, morphology and linguistic variation) are among the reasons why formal languages were invented. Differently from any natural language expression, formulae like those in (25) do not display mophology—nor displacement.

(25) $x = 2 + y^3$

Like INTERNAL MERGE, the operation AGREE is structructure sensitive (as we will see, in more detail, in section 4). That way, the process is never governed by a linear metrics, but a hierarchichal one. In (26a), the verb *venir* agrees with the NP *María*, which is linearly further than the NP *todos los días* (an adjunct); in (26b), the same verb agrees with the N *friends*, wich is linearly further than the N *María*. The interesting case is provided by examples like (26c), where the weak pronoun *me* (Eng. 'to me') blocks AGREE between the matrix verb *parecen* (Eng. 'seem') and the NP *tus propuestas* (Eng. 'your proposals').

(26) a. Here came all days María
b. The friends of María came here every day
c. *Me parecen surtir efecto tus propuestas [Spanish]
to.me seem.3PL have effect your proposals
'Your proposals seem to me to have an effect'

This is only an example that illustrates that basic operations of language, MERGE (external and internal) and AGREE, operate under factors other than linear order. Research for the last forty years suggest that the fact that a word precedes or follows another linearly does not necessarily reflect a basic syntactic relation—it may, as in (27), or not, as in (28):

(27) María says that always

(28) María says always that [OK IN THE SPANISH EXAMPLE]

In the two sentences that form the minimal pair in (27)-(28), we want for the verb *say* to establish a very close syntactic-semantic dependency with the pronoun *that* (the /PATIENT/ of the *decir* action), not with the adverb *always* (an adjunct). In fact, the basic semantic relations are the same in both sentences, which follows naturally if the syntactic dependecies are the same.[11] This said, we must explain how the adverb

[11] Binding of mophological anaphoras provides another argument against the relevance of linear order of syntactico-semantic phenomena. The minimal pair in (i) shows that the anaphor herself must have a close antecedent (an antecedent that is within its clause):
(i) Martha criticizes herself
(ii) *Martha says that John criticizes herself

always can appear between *say* and *that* (which is possible in languages like Spanish, but not English) without that affecting the semantic dependency between the verb and the DO.[12] A plausible explanation is that linear order is determined in the phonetic component, independently of syntactico-semantic processes, and it is there where we also expect to find linguistic variation. If that is correct, the Aristotelian assertion that opened this section, and to which we return, must be qualified.

3. Interfaces: Asymmetries between Sound and Meaning

At the beginning of section 2 we mentioned the Aristotelian conception of language as the union of "sound with meaning." In a sense, hat vision also appears expressed in the structuralist definition of linguistic sign as the "arbitrary union of signified (meaning) and signifier (sound)." The same binary association takes place in any SO or phrase—that is, in the combination of a set of meanings and a set of sounds—but in this case it is not arbitrary; rather, determined by the constituent element and the manner of their construction.

Unlike the lexicon, which is a finite repository of units, I-Language SOs are potentially unlimited, so it is not possible to learn all the associations that can take place. The relevant sound-meaning pairings are, therefore, the result of a mind / brain-internal generative procedure, based on the basic operation MERGE. This idea is embodied in the architecture in (29), where syntax appears connected to the phonetic and semantic components, responsible for the externalization and the interpretation of SOs generated by the operation MERGE. [13]

(i) and (ii) could also be used to indicate that the antecedent (the NP *Martha*) must linearly precede the anaphor. Now, the datum in (iii), which must be compared to (i), excludes that possibility.

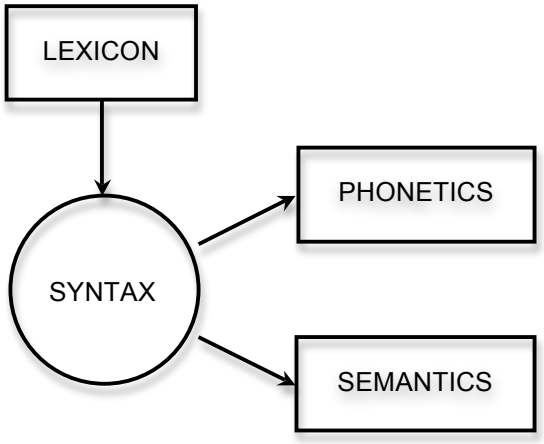
(iii) The friend of Martha criticizes herself

In (iii) we see that the antecedent of *herself* cannot be *Martha*, but the NP *The friend of Martha*. That shows that the relation between anaphors and antecedents does not obey linear order factors either.

[12] This does not mean that (27) and (28) have an identical meaning. In principle, the focus of the sentence in (27) is the adverb always, and that of sentence in (28) is the pronoun. If that is correct, it is more natural to use (27) as a reply to the question *When does María say that?*

[13] It is important to have a grammatical architecture to understand how the different language levels (syntax, lexicon, phonetics, etc.) operate and how they interact with eacu other—issues that, as far as we can tell, are not considered in High School grammar courses. (29) is telling us two basic things: that the lexicon provides the syntax with units to operate and that it is syntax that determines the semantics and (part of) the phonetics of linguistic expressions.

(29) Grammar architecture



SOs built by MERGE yield representations accessed by those components of human biology that have to do with language, but are not strictly linguistic: Conceptual-Intentional systems (or C-I systems, which handle processes of inference, interpretation, planning and organization of action—all we can informally calle "thought")[14] and the Sensorimotor systems (or S-M systems, which handle its externalization by speech or signs). Therefore, there must be a TRANSFER operation that hands over the SOs built by MERGE to the phonetics and semantics, which act as interfaces (interaction zones) with the C-I and S-M systems.

More precisely, we should talk about two independent processes of transfer, as they are quite diferent. The SYNTAX → PHONETICS transfer is complex, for it requires at the very least the conversion of a hierarchical structure without order into a unidimensional one (where linear order can be determined). The SYNTAX → SEMANTICS transfer, on the other hand, is more direct, as hierarchical information and copies, which are crucial to interpretation, is not lost. That is to say, in a sentence like *How many pieces of silver did the priests give Judas?* we want the structural information of the VP, depicted in (30), to be preserved:

(30) [$_{SC}$ How many pieces of silver [did FLEX [$_{SV}$ the priests [Judas [give how many pieces of silver]]]

It is necessary that the semantics can 'see' that the arguments of *give* occupy different positions, for that is the only way for it to assign different interpretations: the NPs *the*

[14] The emergence of a property like MERGE in the mind/brain of human beings provides a "language of thought." We would be, therefore, in front of an internal generative system that builds thought with richness and arbitrary complexity by using conceptual resources probably available to other species, which lack the capacity to combine them in the relevant way. This attributes the key human-animal difference to the syntax, but we do not have to go that far: even the simplest words can express concepts with no counterpart in animal cognition (cf. Gallistel 1991, Fitch et al. 2005, and references therein).

priests, *how many pieces of silver* and *Judas* are interpeted as agent, patient (of theme) and goal respectively.

The precise nature of this process (the SYNTAX → PHONETICS transfer) depends on questions about the interaction of human thought and syntax, for wich we still have only partial answers.

A traditional idea is that TRANSFER applied cyclically: Given a structure [α [β [δ]]], TRANSFER first targets δ, then β, and finally α). This means that when a SO built is sent to the interfaces, it cannot be modified any more. This cyclic process favors the preservation of those dependencies that have been built before TRANSFER, which is an optimal result. Let us see what this means in the case of (20), repeated here as (31):

(31) Achilles defeated Hector

The interpretation of (31) depends on the combination, first, of the verb *defeated* with the NP *Hector* and, subsequently, the resulting VP with the NP *Achilles*. This asymmetry of combination (one NP is merged with V, and the other with VP) provides the key interpretive difference: the NP *Hector* receives the action (it is a /PATIENT/), the NP *Achilles* carries it out (it is an /AGENT/). If the combination was linear (flat), as in (32b), and not (32a), it is not obvious how to reflect the difference we are underscoring.

(32) a. [$_{VP}$ [$_{NP}$ Achilles] [defeated [$_{NP}$ Hector]]]
b. [$_{VP}$ [$_{NP}$ Achilles] [$_{V}$ defeated] [$_{NP}$ Hector]]

Of course, one could try to explain the contrast in linear terms and say that if an NP appears to the right of the verb it is a /PATIENT/ and if it does to the left it is an /AGENT/. But that, quite simply, does not work: *Achilles* is still /AGENT/ even if it appears to the right of the verb in *Defeated Achilles Hector* or *Defeated Hector Achilles*, which are possible in Spanish.

When *defeated* is combined with *Hector*, a dependency between those units is established (both are contained within a VP). Ideally, that dependency should not be modified later on—if it were, then it would be like saying that first application of MERGE creates a dependency that is to be tampered with later on. For all these reasons, the application of MERGE should take place in the most simple possible way: at the top of the structure (33b), not below it (33c). Thus applied, MERGE does not affect the outcome of any previous operation.

(33) a. MERGE (defeated, Hector) = [$_{VP}$ defeated Hector]
b. MERGE (Achilles, VP) = [$_{VP}$ Achilles [$_{VP}$ defeated Hector]]
c. MERGE (Achilles, NP) = [$_{VP}$ defeated [$_{NP}$ Achilles Hector]]

There are empirical arguments (too complex to be discussed here; cf. Gallego 2020 and references therein) showing that the cycles relevant for interface processes

correspond to the VP, where the predication interpretation is fixed (i.e., what verb type we have, how many arguments, how many adjuncts, etc.) and the sentence (the so-called Complementizer Phrase), which determines if an utterance is declarative, interrogative, exclamative, etc.[15] It seems, moreover, that EXTERNAL MERGE provides the first type of semantics, whereas INTERNAL MERGE does the second type. If correct, we would basically have at hand all we need to account for the semantic duality of natural languages. This is not trivial, if we take into account that we only need a lexicon and two basic operations: MERGE and AGREE.

Let us see this aspect with more detail. Let us suppose that an NP in the innermost position of (31) is replaced by an interrogative pronoun. We will then obtain *Achilles defeated who*. Let us next suppose that we merge *who* with all the structure we had assembled so far (internally, therefore). The outcome is (34), with two copies of the NP *who*.

(34) [α Who [β Achilles [δ defeated Who]]]

The representation in (34) gives us the interpretation of the sentence (expressed more accurately in (35)), in the sense that, on the one hand, *Who* is the object of *defeat*, and, on the other, it determines the interrogative modality of the sentence. It does not give us the right externalization, though (we do not utter *Who* twice).[16]

(35) For what x, x = a person, Achilles defeated x

The situation we are describing occurs in all displacement cases, on which there are at least two copies: one in the innermost position (to express the thematic relation between *who* and the verb), and another in the outermost position (to turn the sentence into a question). All this concerns the meaning side. On the sound side, typically, it is the outermost copy that is pronounced, thus minimizing the amount of material that is externalized (keep in mind the discussion about (13) above). It is interesting to emphasize that the minimizing process raises obvious problems for human communication. If we consider a sequence like (36) we can see why.

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[15] For more details about this projection, we refer the reader to Gallego (2016). The CP projection is placed above the verbal inflection (INF, in (23) and (24)) and provides structural space for conjunctions and other elements encoding modality and subordination.

[16] Notice that the analysis in (34) (or any notational variant) is necessary, no matter what. We have an analogous situation in cases like (i), where, again, we must somehow relate the pronoun *who* with the verb *criticize*:

(i) Who does it seem that María said that Elena thinks that ___ criticized everyone?

Although *who* occupies a position internal to the main clause (headed by *seem*), this pronoun is the /AGENT/ of the event denoted by *criticize*. If we endorse the idea that the arguments of a verb are generated in the clause in which such verb appears, then we have to assume that the pronoun *who* is generated in the sentence headed by *criticize* and later on it moves to the position it occupies, at the beginning of the main clause. Many proposals have been put forth to account for this long distance dependency, but the only one that does not require to stipulate additional mechanisms is based on MERGE, an operation necessary for independent reasons.

(36) ¿[$_K$ When did they say [$_G$ that you solved the problem]]?

This sentence is ambiguous between a reading in which *when* is interpreted as an adjunct of *say* and another one in which it is interpreted as an adjunt of *solve*. The ambiguity could easily be solved if the innermost copy was pronounced in the relevant position—inside L or G, depending on what reading we actually intend. But it seems that even when TRANSFER applies, UG chooses the most economic option, spelling out only one copy, putting communication demands to the side.

This takes us right back to the Aristotelian saying about language as a pairing of "sound with meaning"—or, as we believe it should be rephrased, of "meaning with sound." This change of order should make us study how those two systems (phonetics and semantics), so different from one another, are connected. For reasons that have already been expressed elsewhere (Berwick & Chomsky 2016 and references therein), the Aristotelian definition should reflect that the syntax-semantics-C-I systems relation is optimal (less complex) if compared with the syntax-phonetics-S-M systems relation. This is expressed in Chomsky (2014:7) as the thesis T:

(37) T Thesis
Language is optimized relative to the CI interface [thought] alone, with externalization [external manifestation] a secondary phenomenon.

The optimal nature of the SYNTAX → SEMANTICS mapping supports (T), but the most important argument for it comes from structure dependence (see discussion in section 4 below) and so-called reconstruction effects, which follow straighforwardly from the presence of copies (cf. Chomsky 1993; cf. Gallego 2020 for an accessible exposition of the basic facts).

The same holds of the thesis that human language is a mechanism internal to the mind that allows us to deploy a more sofisticated thought, and not merely a communication system.

> The modern conception—that communication is the "function" of language […]—probably derives from the mistaken belief that language somehow must have evolved from animal communication, though evolutionary biology supports no such conclusion, as Lenneberg already discussed half a century ago. And the available evidence is strongly against it: in virtually every important respect, from word meaning to the [discrete infinity and displacement], in acquisition and use, human language appears to be radically different from systems of animal communication. One might speculate that the modern conception also derives from lingering behaviorist tendencies, which have little merit. Whatever the reasons, the evidence available appears to favor the traditional view that language is fundamentally a system of thought.
>
> [from Berwick & Chomsky 2016:102]

The key question here has to do, in the end, with the structures that speakers generate every day (in a creative, spontaneous, way). Galileo was surprised with this capacity of humans, which is at the core of Cartesianism, despite the fact that little attention

was paid to it, probably because of the inertia of traditional explanations (as we will see in section 4). If someone asked about human creativity, the answer—in the past—was based in "induction" or "analogy." It is still today, surprisingly. If that was the case, then all we say every day would be based on a memorization and repetition exercise. But notions like induction or analogy are seldom carefully analyzed—and are closer to hand-waving in the context of the present discussion, as they yield virtually none of the key properties we are considering. Human language is a system of discrete infinity, much like the number system, so it must imply some combinatorial mechanism that forms new objects from objects already formed. That mechanism is MERGE, which cannot be derived by induction, analogy, or any equivalent notion.

Of course, the operations MERGE, AGREE and TRANSFER require much more discussion that we can devote to them here, in part because they raise many questions. Nonetheless, it is important to highlight that so simple a system like the one we have outlined up to this point can cover most of the central phenomena for the study of natural languages. Many of those phenomena are basic and surprising from a naïve point of view—the same point of view that allows us to be puzzled about daily and obvious facts—, like structure dependency, variation in the externalization in the SYNTAX → PHONETICS course, the ubiquity of displacement, and the duality of meaning that a MERGE-equipped system can deploy.

4. Factors to the Study of Language: A Bridge across Disciplines

The goal of the biological perspective we have outlined in these pages is the study of UG, inasmuch as the expression of the faculty of language, a part of human cognition. The biological approach started to take shape in the 50s, as part of the Cognitve Revolution that departed from predominant views at the time, behaviorism and structuralism:

> During the structuralist period […] language was not typically regarded as a biological object, so the question of its evolution could not be raised. European structuralism commonly adopted the Saussurean conception of language (in the relevant sense) as a social entity—or as Saussure (1916, 31) put it, as a storehouse of word images in the brains of a collectivity of individuals founded on a "sort of contract." For American structuralism, a standard concept was that of Leonard Bloomfield, for whom language was an array of habits to respond to situations with conventional speech sounds, and to respond to these sounds with actions; or in a different formulation, language is "the totality of utterances made in a speech community" (Bloomfield 1926, 155). Whatever such presumed entities may be, they are not biological objects.
>
> [from Berwick & Chomsky 2016:95-96]

There are two fundamental issues (two 'problems,' more precisely) that can hardly be approached from a non-biological perspective: Plato's Problem (How do children acquire an I-Language so easily and quickly?) and Darwin/Wallace's Problem (How did the language faculty appear in humans?). If we want to give a solution to these

problems, we have to address three questions at least: What kind of system is an I-Language? How do children acquire it? And why does it have the properties it has (and not others)? Although the first question (which seeks what Chomsky 1965 calls DESCRIPTIVE ADEQUACY) could be said to be present, superficially, in part of the linguistic tradition, questions two and three (concerned with Chomsky's 1965 EXPLANATORY ADEQUACY) are exclusive of the biological approach—in fact, the third question is very infrequent, not only in Linguistics, but in most other disciplines.

It is useful, in this context, to reflect on the origins of sciences in general (cf. Chomsky 2012b). The contemporary scientific revolution started with the attitude by a few to be willing to be puzzled about daily things in the reality that sorrounds us that seem totally simple and obvious. Without going any further, the fact that an apple falls from a tree (or steam rises from a glass of hot water), and why it does at a certain rate (Newton's Problem). For thousands of years, the Aristotelian theory—ridiculous nowadays, but not back then—that things seek their 'natural place' was assumed. However, when scientists of XVII century decided to be puzzled about facts like that, asking why the world works the way it does, they quickly realized that there were many puzzles to be solved. So, for example, Galileo refuted the idea that the rate of fall is proportional to mass by showing in a simple thought experiment that acceleration of objects is constant if air resistance is annuled.

When these questions are addressed, even if only partially, others emerge, many of which still lack an answer today. For example, where is 85% of the matter (so-called "dark matter" and "dark energy") in the universe? The same happens, trivially, with aspects of language that look simple and obvious, so much so that they can look boring. But apples falling may seem, in and of itself, boring too.

Students—and adults, for that matter—don't typically wonder why adjectives cannot be Subjects nor DOs (see (38a)), why elements like *it* (with no meaning in its expletive use) exist in English (see (38b)) or why strong pronouns in DO position must be doubled by weak pronouns in languages of the Spanish sort (see (38c)).

(38) a. {María/*Clever} drank {beer/*nice}
b. {It/*∅} was decided that nobody should leave
c. {La/*∅} llamé a ella [Spanish]
her called-1SG ACC her
'I called her'

Why do all these things happen? Undoubtedly, one can think that these questions make little sense: What we see in (38) simply happens, and that's it. What's interesting about them? To be sure, one can believe that there is nothing interesting about those facts, nothing to be puzzled, nothing to investigate. Nonetheless, if we reflext a bit, we will see that all those facts have not been determined by anybody (unlike irregular verbs and similar facts). The scenario is then different. If nothing in (38) has been fixed by a person or an institution, why does it happen? And, why does it happen in the way it does and not in a different way? The question is more

interesting the moment we pay attention to the fact that those properties do not follow any communicative-driven logic.

Those questions—and others, of course—are interesting, as interesting as the falling of apples from trees is, if they are introduced in these terms, and they allow us to stimulate the curiosity of students. It is more interesting yet, we believe, that we have no conclusive answer to many of those questions, something that can be seen as positive, especially if language teaching, like all teaching, is thought of as stimulating creative intelligence. It is for that reason that, apart from identifying the NP *too much ambition* as a DO in the sentence (39), a student should be able to provide formal arguments that allow him/her to defend that analysis—or formulate principles that explain why (40), a very similar example, is impossible.

(39) In his aim to touch the Sun, Icarus had too much ambition

(40) *In his aim to touch the Sun, Icarus had too much ambitious

Nowadays, at least in countries like Spain, many pages of textbooks are devoted to explain what the syntactic analysis (sometimes, very complex) of structures like (41):

(41) If Luisa leaves her office, I will let you know.

It is not clear to us that this type of constructions must be studied in detail (sometimes with complex tree-shaped syntactic analyses), especially at stages of education previous to college. It is perhaps more useful to offer a more general characterization and leave technical aspects of syntactic analysis for smaller objects (cf. Bosque & Gallego 2016, 2018).

All these issues are related, to some extent, to the distinction between weak and strong sciences (labels that can be misleading, admittedly; see fn. 17). The ultimate goal should be to unify them in some manner—more properly, to incorporate weak sciences into strong ones.[17] In weak sciences, we understand less. If we pay attention to the different disciplines, it is probably Physics where more progress has been made—and keep in mind that, out of all the elements in the periodic table, physicists only understand Hidrogen well. Probably progress is due to the fact that the focus is on very simple objects. If an object becomes too complex for physicists, they leave it to the chemists. If chemists consider an object too complex for them, they pass it to biologists. If a biological system is too complex, biologists leave it for sociologists or psychologists. And if the object is too big for everyone, then someone writes a book or a blog entry about it. Needless to say, we are exagerating, but not too much. The

[17] This is not necessarily so. That is not what happened with Physics and Chemistry, for example. Rather, a radically revised Physics was able to incorporate a virtually unchanged Chemistry. This could well happen with linguistics and the brain sciences. Needless to say, talking about "weak" and "strong" sciences seems to us misleading in this particular case. Chemistry was not weak, and a great deal about it was understood by then.

idea we want to convey is that the more complex an object of study is, the more difficcult it is to provide an explanatory analysis, an analysis that makes students understand—one could, at most, offer a superficial (and probably partial) characterization.

Let us give an example. A very simple aspect, apparently obvious and daily, about language: stucture dependency. In sections 2 and 3, we saw that linguistic objects display a linear order and—more controversially—that such linear order does not necessarily interpretation. The operation MERGE generates objects with the form $[_K \alpha, \beta]$ and determines structural dependencies (α y β belong to K, not vice-versa), not linear ones ($[_K \alpha, \beta] = [_K \beta, \alpha]$). Languages differ in the manner in which SOs generated by MERGE are uttered, an important research topic that concerns the interaction of syntax and the systems responsible for the externalization of thought. In English, the DO is to the right of the verb and in Japanese to the left. This change does not feed interpretation, which is the same in both languages, suggesting that syntax (and semantics) is the same, only exteriorization changes.

A direct consequence of this way of seeing things is structure dependency: if linear order is a morpho-phonological factor, there should be no syntactic operation that makes use of that information.[18] We have seen that in the case of AGREE (the example in (22) above). Let us see it in the case of displacement (INTERNAL MERGE). Consider the yes-no question in (43), which is built from (42), where we indicate the original position of the verb *say* with ___ .

(42) Politicians say lies

(43) Say politicians ___ lies?

From this, one could think that the rule applied to build (43) is (44):

(44) Move the first verb that we find linearly to the first position of a sentence

The rule in (44) works fine with sentences that have only one verb, like (42). However, when we have a more complex structure, like (45), things are more interesting.

(45) [$_\alpha$ The [$_\beta$ politicians [$_\delta$ that say lies]] steal]

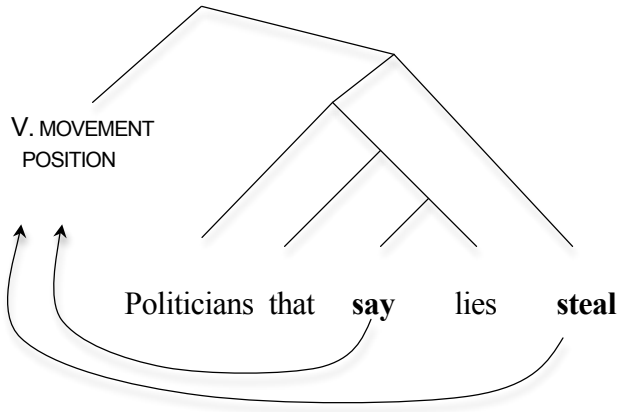
In this case, the application of (44) gives (46) as result, an ungrammatical sentence.

[18] This excludes the existence of languages that, though logically possible, cannot be acquired. We mean languages whose operations are defined though linear-order based rules (e.g., "revert the order of words to formulate a question"). There are results that indicate that such hypothetical languages do not enter into the variation that UG allows. In fact, those "invented languages" are treated by speakers as noise, not true linguistic data. In those studies it is shown that brain activity is fuzzy (it shows up in many brain areas), something that differs from what has been observed in the use of natural languages (cf. Musso et al. 2003).

(46) *Say [α politicians [β that ___ lies] steal?

The right result follows by moving the verb that we find in the first position hierarchichally, not linearly, apparently a property of UG. In structural terms, *steal* (the verb in the main clause) is closer to the position targeted by displacement than *say* (the verb in the embedded clause), for the latter is within a relative clause internal to the NP headed by *politicians*, as depicted in (47):

(47)



say = closer linearly, not structurally
steal = closer structurally, not linearly

We must conclude, therefore, that children somehow discriminate data that present human language properties (from all the input they receive), and which are not governed by linear order. We are before another PoS example, which is easily explained by MERGE, as this operation is only structure, not linear order, sensitive.

Before concluding, we would like to go back to the questions that the biological approach to language allows us to ask, focusing on the second and third questions: How an I-Language is acquired? And why it is the way it is? The second question takes us to at least three factores that are necessarily implied in the growth and development of any organism or biological property (cf. Chomsky 2005): (i) genetic endowment (in the case of language, expressed in UG), (ii) external stimuli (the exposition to data in a given linguistic community), and (iii) language-independent laws of nature that 'channel' form and development.

In principle, these factors can interact in many ways. An interesting example comes from the role that economy principles play, which can be seen in the language acquisition process (cf. Yang 2006, 2016) and grammatical operations themselves (cf. Chomsky 2000, 2013), which considerably reduces the burden of factor (i), UG, a desirable outcome in evolutionary terms—given its recent appearance, we expect for UG to be as simple as possible, perhaps even almost empty (cf. Chomsky 2004).

We have another example in the fact that the development of growth can modify the genetic expresion, which could mean that UG (the first factor) might be different in an adult and a child. There is no evidence that things are that way, but we must consider such possibility. There is another factor that enters into growth and development of human beings that deserves attention: brain structure. As far as we can tell, the brain is designed in such a way that only allows certain paths of growth and development of cognitive organs (cf. Friederici 2017 and references therein). This is another terrain where, again, we barely know something, too little to keep it in mind when studying *how* questions.

Let us go back, fnally, to the *why* question, which is relevant when looking for answers to *what* and *how* questions. Since language is a mental computation system (through MERGE, which combines units externally and internally), a factor that we want to control is computational efficiency, probably a law of nature. To be sure, we do not have a general theory of computational efficiency, but we do have some observations that are pretty obvious and should be part of that theory. One is that "less is better than more," so a system with one rule is, *ceteris paribus*, better than a system with two; or that grammatical dependencies (agreement, displacement, Case assignment, etc.) must apply minimizing distance, not maximizing it. We will not dwell on them, but nowadays we know many concrete examples of minimal computation principles, present in language, which are part of biological laws or perhaps a theory of computational efficiency, present in language (cf. Gallego 2020 for an accesible general summary).

In this section we have focused attention in two problems that cannot be seriously addressed, not even posed, from a non-biological point of view: Plato's Problem and Darwin/Wallace's Problem. These two problems have taken us to consider three factors that seem to be involved in the development of language, as much as they are in any other system of nature. All of it highlights an aspect that we regard as fundamental in scientific attitude: the will to be puzzled about daily and apparently obvious phenomena.

That will is what allows us to ask questions like the ones we have put over the table. It allows us to establish obvious connections with disciplines like Physics, Biology and Mathematics (cf. Uriagereka 2005 for seminal ideas). A direct consequence of this scientific approach, we believe, should be the reduction of grammar contents in language courses in High School, at least in those education systems in which the study of language covers from the sounds of language to discourse. Science *moves forward*—and we *understand* the world that sorrounds us—by asking simple questions about simple objects. This does not mean that language courses must supress the teaching of grammar, but they should probably revise the amount of contents, making those that are studied be seen with more calm depth, from a more general and biological angle.

5. Conclusions and Open Matters

Language is a complex object of study. It has social, politico-cultural and artistic dimensions. Those at least, probably more. In this paper we have defended that there is a dimension that we have referred to as biological, barely known in the basic levels of education (and the society, more generally), which begs a series of questions that can make the study of the faculty of language interesting and full of challengues. On the one hand, that perspective allows us to study the most defining trait of human cognition (language and its relation with thought), so that it can be a true "window into the mind." On the other hand, it makes it possible to establish cross-over relationships with scientific disciplines, as we just said. The connections between Linguistics and Biology and Mathematics can already be found in the first works of the biolinguistic approach, in the 50s and 60s (cf. Lenneberg 1967, Chomsky 1956, 1959, Chomsky & Miller 1963; cf. Benítez-Burraco 2009, Mendívil 2009, for a more recent discussion), but there has also been progress with interactions with Physics and Chemistry in the last decades (cf. Gallego & Martin 2018, Gallego & Gutiérrez in progress for an overview).

We hasten to say that the biological perspective is not incompatible with others, although, for obvious reasons, there are specific aspects in which some of them see things differently. This recalls the old parable in which a group of blind scientists touch the body of an elephant, each of them concentrating on a different part. When they compare their results, the scientists realize that none of them comes together, which leads to an endless argument over who is right. There are optimistic versions of the story in which the scientists realize that they are wrong and start to integrate their perspectives, which gives rise to a more complete and unified description of an elephant-like creature. The moral is simple: thinking that there is only one way to approach the facts typically leads to a partial (or distorted) view of reality. In general, it is more productive to consider things from different angles. And that is not easy. It requires, among other things, the will to cooperate with others (often, from opposite positions) to understand the nature of things.

There are many ways to develop the biological perspective. Although we will not put forward any specific proposal here, we would like to point out that a non-trivial obstacle has to do with the fact that this approach has not been spread at the relevant education levels. We have explored the non-negotiable properties of the faculty of language by introducing the operations of MERGE and AGREE. That suffices to cover a great deal of the concepts that appear in manuals and textbooks (constituent structure, transformations, syntactic functions, etc.), whose precise formulation and contextualization should be reconsidered. The new approach should, we insist, reduce the amount of contents that are seen in the study of grammar; that would avoid many redundancies and would make it possible to reinforce the students' understanding, and stimulate their curiosity at the same time. Grammatical analysis should, therefore, focus on small objects, even if only for methodological reasons: the more manageable the object of study the more understanding we will get. This working plan would also allow the application of strategies and tools (minimal pairs, ungrammatical

sequences; cf. Bosque & Gallego 2016) that brings the study of language closer to other scientific disciplines, with which it should converge.

We leave it here, putting aside many questions that would deserve a more in depth discussion. We hope, nonetheless, to have been able to convey the idea that the study of language from a biological point of view is an activity with a value and interest of its own. This point of view embraces many ideas from the tradition and sets them in the contemporary context, allowing a privileged connection between the study of the very human cognition's nature (what makes us unique among animal species; cf. Chomsky 2017, Berwick & Chomsky 2016) and experimental sciences, a rather un-charted scenario in which there are many issues to address, many problems to solve, many things to be puzzled about.

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