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THE IMMUNE SYNTAX: THE EVOLUTION OF THE LANGUAGE VIRUS[1]

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Summary: Studies on the evolution of language have finally come of age, as the very useful recent work by Hauser *et al*. (2002) aptly shows. By separating a broad, ancient aspect of the faculty of language from a narrower, very recently evolved one, this piece creates a clean research space without clouding anybody's picture. The present paper can be seen as a follow-up in the program towards understanding the narrow faculty of language, taken as the basis for the universal syntax of human languages. We start with a dozen established, to our mind irreversible, results in formal grammar and also a quick presentation of the basic tenets of modern evolutionary theory (the result of an emerging synthesis between neo-Darwinism and the sciences of complex dynamic systems). At first it would seem as if formal syntax is a challenge to evolution, but this is only if the grammar is seen at a superficial level of abstraction and evolutionary theory with the eyes of the nineteenth century milieu where it was advanced. Instead we propose to take so-called minimalist syntax seriously, suggesting that some of its metaphors (e.g. a 'virus' theory of morphological checking) are more than that. We specifically link that kind of syntax with the workings of very elementary levels of biological organization, such as the structure of the adaptive immune system and its biochemical base. Just as this sort of system seems to have evolved in large part as a result of intricate interactions between viruses and hosts, so too we claim that the narrow faculty of language may have had a similar, though of course much later, origin.

The evolution of language still remains speculative, but one can nonetheless begin to steer a course toward plausible conjectures. Paraphrasing the title of a famous paper by Warren S. McCulloch (reprinted in 1988), we need to ask two strictly related, yet distinct, questions:

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What is language that it may have evolved? And what is evolution that it may apply to language?

14.0 WHAT IS LANGUAGE THAT IT MAY HAVE EVOLVED?

Natural languages are rich “objects” to which a variety of characterizations truthfully, though not always relevantly, apply. As is invariably the case with complex natural objects the traits that turn out to be scientifically productive and genuinely constitutive are not simply “there”. It took biologists centuries to realize how productive it was to focus on the property that makes “like beget like”, rather than on the property of being capable of self-initiated motion (the original meaning of the word “animal”, from the Latin anima “air breeze”). Analogously, physicists took centuries to realize how productive it was to chart trajectories and velocities of mobiles in the presence of measurable fields of force, rather than exploring the (alleged) tendency of each category of objects to reach its “natural” place of rest. Likewise, it has taken a long time for the science of language to finally converge onto traits that are genuinely constitutive, unique, and interestingly counterfactual-supporting. Many alternative and prima facie relevant characterizations have been explored. For instance, languages are, no doubt, symbolic systems, composed of arbitrary “signs”; but attempts to capture in depth what all symbolic systems have in common, qua symbolic systems, have proved to be relatively unrewarding. Ditto for the properties of languages as systems of communication, shared “conventions” and ever-changing surface forms. Far from being obvious, the truly constitutive properties of language turned out to be rather subtle and somewhat surprising. The following is a sample over which a more or less general consensus has emerged over the decades.

14.0.1 Constituent Structure

Linguistic expressions have parts that enter into combinations. This much is also true, in some sense, of a few animal communication codes. Constitutivity as such, however, is more than a mere part-whole relation, and in the foregoing sense is clearly unique to human languages. Linguistic constituents (i) are abstractly characterized, (ii) possess internal hierarchical structures, (iii) belong to a remarkably short, fixed list of classes across all languages, (iv) are the direct basis of human semantic composition.

14.0.2 Discrete Infinity and Recursion

The outputs of animal communication systems are either in principle infinite and continuous (e.g. variable intensity of birds' calls -- Marler 1957 quoted in Hauser, 1996, p. 53), or discrete and finite (e.g. rhesus monkeys call types, Hauser and Marler 1993, cited in Hauser, 1996, p. 104) (Hauser, 1996). Human languages, in contrast, are discrete and in principle infinite. Thus, there is no conceivable continuum between two sentences like:

(1) a. It's a good car, but they don't sell it [i.e., the car].

b. It's a good car, but they don't tell it [i.e., the fact that the car is good].

Moreover, there can be no use for such a thing as a "fraction" of a morpheme or phonological feature (+/- voiced, +/- occluded, etc). In turn, even children's rhymes speak of cats that killed rats that ate the malt that lay in the house that…, which obviously can in principle go on forever. It has been suggested (e.g. by Chomsky 1988) that this sort of discrete infinitude may relate to that found in number systems, which are also uniquely human. The process whereby operations can apply to the abstract (non-terminal) output of previous operations, in principle indefinitely, is called recursion. This mechanism gives mathematical substance to the (ultimately Cartesian) intuition that human language is endlessly creative, and to the Humboldtian (von Humboldt, 1836) remark that it obtains unbounded expressiveness with finite means.

14.0.3 Displacement

At variance with formal languages (notably, predicate calculus), natural languages present elements that receive an "elsewhere" interpretation: They are processed as if located at a different place in the sentence. For instance, in the interrogative *Which book did you read?* or topicalizations such as *This much, I do know*, the constituents *which book* and, respectively, *this much* appear in sentence-initial position, but we tacitly understand them as being positioned right after the verb, in the canonical object position. These constituents have been "moved" from their canonical (declarative sentence) position onto their manifest one, leaving behind a remnant "trace", which receives no phonological expression. This constitutes a discontinuous relation between elements of the sentence that cannot be captured in mere phrasal terms.[2]

14.0.4 Locality

Syntactic relations are local, often taking place between elements that are, in a sense that can be characterized precisely, very "near by" within a phrase-marker. This is true, at the relevant level of abstraction, even about movement phenomena, which turn out to be extremely constrained. First, they typically proceed "upward" in a phrasal representation (the technical term is to "command" positions). In turn, although movements can in some instances span over ultimately unbounded domains (*which book did you say he thought she claimed … you read*), whenever this happens it can be shown that the unbounded relation is broken down into smaller steps called "cycles". This is witnessed in some languages (e.g. Spanish) by way of a concomitant process that accompanies the hypothesized local (or cyclic) movement. Thus in

[2] Different theories have been proposed to account for these phenomena (see for instance Sells (1985), Graffi (2001)), but regardless of whether constituents are taken to be displaced, discontinuous, involving graphs where branches can cross, or feature sharing across nodes, the point remains that these are context-sensitive relations, in a sense to be discussed further.

(2b) we observe (vis-à-vis the declarative (2a)) how intermediate verbs invert over the corresponding subjects when question formation proceeds long distance:

(2) a. Tú dices que él piensa que … tú has leido un libro
you say that he thinks that you have read a book
b. Qué libro *dices tú* que *piensa él* que … tú has leido?
Which book say you that thinks he that you have read

Torrego (1984) plausibly interpreted these facts as demonstrating a side-effect of successive cyclicity (the displaced verb is associated to the "trace" left by the moved Wh-phrase); many other studies have shown similar effects for scores of entirely unrelated languages.

14.0.5 Redundancy

Classical grammars were very preoccupied with the proper morpho-syntactic relations between lexical items: a speaker who cannot master these dependencies is a poor speaker. But, in hindsight, the traditional notion of "agreement" highlights the fact that not everything that is actually pronounced is needed by the interpretive apparatus. Even morphologically "impoverished" languages like English express on the surface more than they need to, if judging from a more abstract level of analysis. In a strictly semantic sense, it is clear what the subjects of the verbs are in the English examples in (3) or in the Italian equivalents in (4):

(3) a. John says. b. They say. c. We say.

(4) a. Gianni dice. b. Loro dicono. c. Noi diciamo.

Therefore, the morphological flexion signaling in the verb the singular or the plural, or even the person in the Italian instance, is entirely redundant. As a point of contrast, formal languages such as predicate calculus do away with these redundancies and concentrate on thematic relations and their carriers, unifying tensed verbs, infinitivals, participles, adjectivals and nominals. A core hypothesis in the recent Minimalist Program is that, in all languages and at some level in the syntactic derivation, such redundancies are checked out one with the other, and then literally expunged "as soon as possible", in a manner that we return to.

14.0.6 Limited Linguistic Differences

A prima facie tension emerged early on in generative grammar between the progressive discovery of "deep" elements of the language faculty, presumably internally caused and common to all languages, and the manifest diversity among spoken languages. The very idea of a Universal Grammar needs to be reconciled with linguistic variation. The "Principles and Parameters" model was developed in the early eighties as an attempt to reconcile UG and variation by means of severe restrictions on the number and kind of possible inter-linguistic variations. It is as if UG embodied a panel of binary “switches” (Higginbotham, 1982), leaving each language free to choose one of the admissible values for each switch. The manifold diversities among all known languages has been mapped in large part onto a relatively small set of binary options (Baker, 2001). At odds with what a tradition dating back to the early nineteenth century had assumed, languages cannot diverge insensibly over time, cumulatively and without limits. Rather, the possible points of variation are fixed, few in number, possibly hierarchically organized, and each one only admits very few options.

14.0.7 Learnability

It has been all to the advantage of linguistic theory in the generativist tradition to have turned away from any inductive mechanism in explaining how the child “acquires” her native language. A revealing switch from the term language “learning” to the expression language “acquisition” marks this momentous conceptual transition. Ever since Chomsky (1955) (implicitly, and explicitly in Chomsky, 1965) a strict requirement was imposed on acceptable theorizing about the nature of UG: Any posit, mechanism, principle, rule or constraint that may be tacitly known by the speaker-hearer as part of UG must either be innate, prior to any evidence, or be accessible to the child via a direct mapping of the relevant components of UG onto the relevant linguistic input from the surrounding community. Primary Linguistic Data must contain fragments that allow any child to quickly, effortlessly and un-ambiguously converge upon all the parametric choices made by the surrounding linguistic community. Far from being a lengthy process of trial-and-error, propelled by inductive guessing, language acquisition consists of a (possibly random) cascade of discrete selections, as the child’s linguistic system stably “locks onto” the values of each parameter. The relevant fragments of linguistic input have been, revealingly, called “triggers” (Dresher, 1999; Fodor, 1998b; Gibson and Wexler, 1994; Lightfoot, 1999). Linguistic theory is constrained to offer only hypotheses that, in principle, satisfy the learnability requirement.

14.0.8 Autonomy of Syntax

The autonomy of syntax was suggested already in medieval, so-called Modistic, theories of language and grammar (Graffi, 2001), and was forcefully revived by Chomsky’s famous *Colorless green ideas sleep furiously*, a meaningless sentence that English speakers straightforwardly judge to be syntactically impeccable. It has proven productive to explore this general thesis in terms of what may be thought of as a “narrow” faculty of language (FLN), vis-à-vis the motor, perceptual, cognitive and intentional systems which this faculty interfaces with. In a broader sense, the faculty of language (FLB) includes an internal computational system combined with other organism-internal systems (“sensory-motor” and “conceptual-intentional”). In contrast, although FLN is a component of FLB, it constitutes solely the computational system, independent of what it interfaces with. FLN generates internal representations and maps them onto the interfaces via the phonological system and the semantic system.

14.0.9 Full Interpretation and Compositionality

A surprising fact about human semantic interpretation is that it exhaustively applies to all symbols, involving all relevant syntactic elements in a piecemeal fashion (the Principle of Full Interpretation). Thus the process is entirely different, at least at the propositional level, from the holistic way in which ciphered messages typically work (e.g. “knock on the door three times and you’ll get access”). In addition, it has been shown that human language is “compositional”, in that the meaning of an expression X is a direct consequence of the meaning of X’s parts and the way in which they combine. This proposal has been strengthened even to a “Strong Compositionality Thesis”, as expressed for instance in Larson and Segal (1995:78): “R is a possible semantic rule for a human natural language only if R is strictly local and purely interpretive.” Strictly local means that R cannot look down any deeper than the immediate constituent (“sister”) of a given category X to interpret this category. Purely interpretive means that R cannot actively create structure of its own, it only passively interprets structure given by the syntax. In other words, human semantics narrowly tracks all and only syntactic elements, and interpretation crucially depends on this correspondence.

14.0.10 Conservativity

The last property we want to discuss is a bit harder to understand if one is unfamiliar with set-theory or linguistics. Nonetheless, as it is an important semantic result (perhaps the most decisive), we would like to mention it. Readers who do not follow the following paragraphs will nonetheless be able to understand the logic of the paper. The point is based on the idea that natural language determiners (e.g. articles) relate sets, thus are taken to be predicates 'D (Y) (X)' with two arguments: their “restriction” (e.g. the set Y of men) and their “scope” (e.g. the set X of islands) to yield such expressions as “no man is an island”. Importantly, determiners in human languages are “conservative” (Keenan and Stavi, 1986), which can be characterized explicitly as follows: for any X and Y, arguments of determiner D, the semantic value of 'D (Y)' is identical to
'D (Y) (X $\cap$ Y)'. Consider this for an “intersective” determiner like *some*:

(5) a. Some Basques are Spaniards.

b. Some (Y) (X) iff the intersection of X and Y is non-empty.

If some Basques are Spaniards then some Spaniards are Basques. In general, for an intersective determiner D, 'D (Y) (X)' is true iff $Y \cap X$ has some characteristic; intersecting Y and X yields the same as intersecting Y and X and then intersecting that with Y, i.e., $Y \cap X = (Y \cap X) \cap Y$ (i.e., “conservativity”). “Non-intersective” determiners are conservative too. A non-intersective determiner is one for which the truth of a proposition introduced by it does not rely only on characteristics of elements in the intersection of the two sets, contrary to what is seen in (5a), where the determiner is intersective. Thus:

(6) a. Most Basques are Spaniards.

b. Most (Y) (X) iff the intersection of X and Y is larger than half of Y.

Intuitively, the arguments of *most* are not “interchangeable” (*most Spaniards are Basques* is not equivalent to (6a)). So in order to account for the conservativity of a determiner like *most* (most Basques are Spaniards iff most Basques are Basque Spaniards) we must somehow order its arguments, 'D <Y, X>'. In other words, unlike *some*, which can be seen as an “intransitive” determiner, *most* is “transitive”, in some sense. That is an interesting property of this sort of determiner, since whereas it is easy to see how *most* can relate to its restriction (in (6a) “Basques”, interpreted from the complement of *most*), it is harder to see precisely how it can relate to its scope (in (6a) “those who are Spaniards”, an element which is not in construction with *most*). Scope is, in effect, a derived argument, particularly if strong compositionality is assumed. In that respect, note that not even the conservativity of the intersective *some* in (5) is trivial, since again the scope of this determiner is a derived argument (something which is easier to see when a quantifier is in object position, as in *he found no opposition*, where the scope of *no* is “he found x”, or “that found by him”). The fact that these tasks are nonetheless achieved by grammars illustrates how powerful the human language machine turns out to be.

14.1 What is Evolution, That it May Apply to Language?

The canonical picture of evolution is well-known: new traits emerge by means of small cumulative inheritable variations that are adaptively selected. This captures a real process, but it is by no means the only evolutionary process, probably not even the most important one in biological speciation. The capital role of discontinuous pleiotropic mutations (i.e., those happening in a gene that affect many traits at once), spandrels, genetic recruitment and serendipitous selection need not be defended here. We limit ourselves to applying these insights to the possible evolution of language. We will insist, however, on the possible role of “horizontal” genetic transmission (from viruses to parasites, to transposable elements). Before we do that, a brief summary of the concepts and mechanisms of the standard “vertical” transmission that have greater relevance to our hypotheses may be useful.

14.1.1 A Tendency to Depart Indefinitely

Many systems, in nature and culture, undergo change over time, which is sometimes governed by deep regularities. Biological evolution, though, is a rather special case of change, as it is mostly (though not exclusively) driven by inheritable differential fitness across populations of interbreeding organisms. There is no “departure point” and no “terminal point”. There are no “ideal types” such that a given phenotype is meaningfully gauged as being closer to, or further away from, any of them. In Darwin’s and Wallace’s felicitous phrasing, variants can have a tendency to “depart indefinitely” from the original form. This remains true in the main, even if recent theories have rightfully emphasized the pivotal role of global structural constraints, of “laws of form” resulting from physical, chemical, biochemical and/or systemic necessities (and, in the case of the brain, presumably also emergent computational global constraints).

These are not, nor could be, genetically specified. Rather, genetic specifications and genetic changes must be deployed inside these structural channels, without the possibility of overriding them. The tendency remains mainly true also in the face of the forced stability of regulatory genes, whose changes would perturb too many traits at once (Schank and Wimsatt, 2001).

14.1.2 Some Dynamic Considerations

Fitness is a quantitative property of the cross-generational interaction between competing organisms and their environments, but it is the *differential* fitness of similar phenotypes, one with respect to the other, that matters to the process. That is, while the interaction is shaped by the phenotype, differential fitness is determined by the underlying genotype, which is best defined as a "norm of reaction" to different environments. Other conspecifics (notably other competing variants in the population) and other species, are part of the environment, and therefore components of the differential fitness vector of each individual (Michod, 1999). Let's stress also that differences in fitness may be non-transitive, when environments vary. For instance, variant A can have greater fitness than variant B, when they are alone to compete in a certain environment, and the same may apply to variant B vis-à-vis C in that same environment, but it may well be the case that C has greater fitness than A when *they* are alone to compete, or when A, B and C *all* compete, or when the environment changes even slightly (Lewontin and Cohen, 1969; Sober, 2001). We stress this because all gradualist adaptationist explanations of the emergence of a trait tacitly (and crucially) take transitivity for granted. Small random changes in the genotype must, in those stories, map onto small changes in the phenotype, and selective forces must then drive the process under strict transitivity. No transitivity, no story. Another important consideration concerns factorization or modularity: Some components of the phenotype may undergo genetic change without affecting other components. This constitutes a powerful boost to the "search" process of the genotype across the fitness "landscape". Good solutions for a trait can be preserved in the search of better ones for a different trait. Finally, we must stress the multiplicity of levels of selection (Lewontin, 1970), because optimization at one level frequently imposes sub-optimal solutions at others (Gould, 2001; 2002; Lewontin, 1970; Michod, 1999) . Biological evolution is the global outcome of distinct mechanisms of change and selection taking place at several distinct, though interacting, levels. Global tradeoffs are the rule, rather than the exception.

14.1.3 The Long-term Effects of "Jumping" Genes

All of what we saw in the previous section, at least, applies to the complex evolutionary processes driven by vertical genetic transmission. Consider next briefly the contribution of "horizontal" transmission of mobile DNA sequences, called transposable elements (TEs), that are pervasive in the genomes of bacteria, plants and animals. These elements replicate fast and efficiently and it is common to find hundreds of thousands of copies of such elements in one single genome. Initial sequencing of the human genome (International Human Genome Sequencing Consortium, 2001) revealed that as much as 45% of the total is constituted of DNA that originated from TEs. (This estimate is rapidly increasing with the subsequent sequencing of the more repetitive fraction of the genome). Positive selective pressure for their fast replication at the DNA level suggested the label (and the concept) “selfish DNA” (Doolittle and Sapienza, 1980) and (less malevolently) “junk DNA”. Myopic positive selective pressure at the basic DNA level may well have been the normal case, but in recent years well-supported hypotheses have been advanced of positive selective pressure also at the host level. Stable insertion of transposons, that evolve new coding and/or regulatory functions, has also occurred, with sometimes dramatic evolutionary consequences.

In addition to the normal mode of vertical transmission from parent to offspring within a species, transposable elements can sometimes move laterally between species, a phenomenon known as horizontal transfer, Once these rare horizontal transfers of genetic material have successfully taken place, then ordinary “vertical” transmission perpetuates the new genome. Kidwell and colleagues (Kidwell, 1994) have painstakingly reconstructed such process of horizontal transfer followed by invasion within the recipient species of *Drosophila*, across the whole earth within the last half century. One possible mechanism of horizontal diffusion is likely to have been mediated by parasites mites feeding promiscuously on eggs of several *Drosophila* species, and thereby contaminating one species with transposable elements picked up from another species). Much closer to us, Agrawal *et al*. (1998) and Hiom *et al*. (1998) have persuasively suggested that the immune system of higher vertebrates is the product of the activity of a TE that was “domesticated” following horizontal transfer from a bacterium millions of years ago. Antigen receptors, a key feature of adaptive immunity, are assembled from gene segments by a site-specific recombination reaction. The proteins encoded by the recombination-activating genes, RAG1 and RAG2, are essential in this reaction, mediating sequence-specific DNA recognition of well-defined recombination signals and DNA cleavage next to these signals. Recent evidence suggests that RAG1 and RAG2 were once components of a transposable element, and that the split nature of antigen receptor genes derives from germline insertion of this element into an ancestral receptor gene soon after the evolutionary divergence of jawed and jawless vertebrates. In addition to coding information, important gene regulatory functions are currently hypothesized to have originated from TEs that have, long ago, managed to insert themselves into the germ-line of eukaryotes (Britten, 1997; Kidwell and Lisch, 2000). Phylogenetic analysis has indicated that one major subclass of TEs, the LTR retrotransposons, is closely related to retroviruses. Indeed, sometimes these TEs behave like retroviruses, and vice-versa. A point we wish to emphasize here and now, is that the combined evolutionary role of TEs and viruses adds a significant new dimension and previously unsuspected mechanisms enabling rapid spread of major genetic changes. We argue that this may have been significant in language evolution.

Once these rare beneficial “horizontal” transfers of genetic material have successfully taken place, then ordinary “vertical” transmission perpetuates the new genome. Since, as we have just stressed, many kinds of transposons also code for their own transcription enzymes (a necessary, though by no means sufficient condition) conversions from TE to virus and vice-versa are possible. Under these conditions, such a mechanism becomes, biochemically speaking, straightforward, even though the probability that a major positive alteration of the host’s genetic functions may ensue remains exceedingly small. The momentous RAG story sketched above as the origin of the immune system is rapidly becoming a textbook case, largely also because of its extreme rarity. Once such a rare event of novel genetic insertion takes place, some adaptive selection pressure must be invoked to explain the fixation of the new trait. For the immune system, the reasons for a positive selection are very transparent. In the case of our hypothetical language evolution several nuanced considerations have to be developed, as we try to detail throughout this paper.

14.2 STRUCTURAL PERFECTION IN LANGUAGE

The traditional gross factorization of the language faculty into a "sound" system, a "words" system, an interpretive-semantic system, and a combinatorial-syntactic system, though phenomenologically real, does not withstand serious scientific scrutiny. The distinction between sounds and words, words and sentences, or sentences and their corresponding meanings, are nowadays seen as the stable results of dynamic interplays between abstract components of an elementary computational system and its interfaces. It is not easy to exemplify this in brief, but an illustration can be provided.

Take recursion in the sense above and all it presupposes (constituent structure) and it entails (discrete infinitude). Nowadays this process is seen as optimal in a grammatical system of the assumed complexity. A binary *Merge* operation is assumed to put together arbitrary linguistic constituents in such a way that one of the merged elements preserves its identity (its categorial type, whether it is a noun, verb, etc.) in the process. Since Merge is sensitive to categorial type, type-conservation upon Merge entails that successful merging combinatorics (e.g. a noun phrase and a verb) can be repeated *ad infinitum*, thus guaranteeing recursiveness. Chomsky (1995; 2000) has shown that these particular combinatorics are the simplest there could be, among other imaginable ones (e.g. ternary or n-ary Merge, Merge which is not conservative of category type, etc.). In turn semantic compositionality is in large part based on the Merge operation, guaranteeing that syntactically merged interpretable constituents enter into viable semantic relations. Thus although syntax is in principle distinct from corresponding semantics, the latter emerges within the confines of the former. This tight connection between form and meaning indicates that the Merge process is virtually conceptually necessary, and thus the implied system virtually perfect for the task.

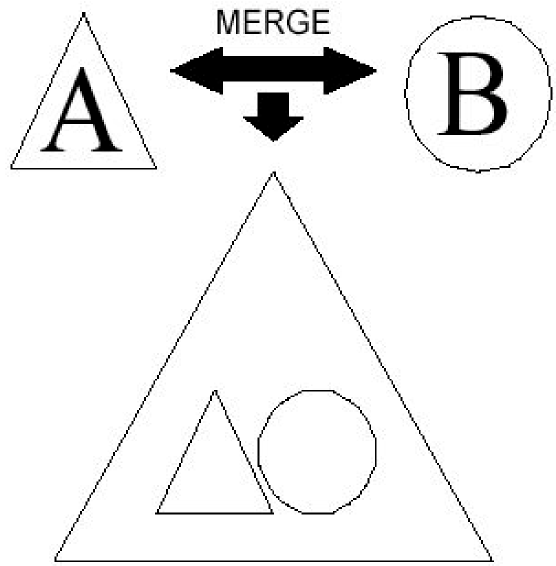

Figure I: 'Merge' produces a larger object which conserves its type.

In this context, the older evolutionary puzzle represented by the utter uselessness of each of the traditional components of language in the absence of all the others gives way to a set of different problems. We had such a puzzle only within a crude adaptationist-functionalist framework, assuming that communication and concerted action were the selective forces, acting on a cascade of cumulative point mutations affecting (presumably) separate capacities: phonatory, lexical, semantic and syntactic. It was, no doubt, perplexing in the traditional view that the overall faculty of language could have evolved gradually, given that small improvements in one component are non-adaptive in the absence of parallel improvements in the others. But the present picture is radically different, in particular Chomsky's hypothesis that the narrow faculty of language is structurally "perfect". Of course, this is apt to strike a sensitive chord in evolutionary theory. The existence of "perfect" organs has long been a stumbling block for classical neo-Darwinism. To witness is (alas) the fact that creationists have used this as "evidence" against evolutionary theory (Schank and Wimsatt, 2001). In short, evolutionary tinkering cannot lead to perfection. In fact Chomsky candidly admits that the perfection of FLN, is "surprising, if true" (Chomsky, 1995:168), and it makes linguistics more similar to physics than to biology. This puzzle, however, can be re-sized considerably with convergent considerations from three independent fronts. One is evolution-theoretic, one ethological, and a third one historico-linguistic. Let's examine them in turn.

14.2.1 Other Optimal Solutions in Biological Evolution

The (quasi-)perfection of some biological structures turns out to be less incompatible with ordinary evolutionary mechanisms than has been assumed. Demonstrable factorizations of genomes into modules and cumulative, autonomous modular improvements of each of them defuse considerably the prima facie paradoxical nature of perfect biological structures. Other factors leading to optimal solutions have also been detected. A revealing instance is the analysis that West *et al*. (1997) provide of the cardiovascular system of vertebrates as a fractal space filling network of branching tubes, under the assumption that the energy dissipated by this transportation system is *minimized*. Biological diversity, from metabolism to population dynamics, correlates with body size (itself varying over 21 orders of magnitude). Allometric scaling laws typically relate some biological variable to body mass M, by elevating M to some exponent *b*, and multiplying that by a constant characteristic of a given organism. The assumption that a standard (3 dimensional) volume is involved leads one to think that *b* should be a multiple of 1/3, so that the cubic root of an organism's mass relates to some of its internal functions. Instead, what researchers have found is that *b* involves not cubic roots, but rather *quarter* roots, unexpectedly, at least if one is dealing with standard geometric constraints on volume. For example, the embryonic growth of an organism scales as $M^{1/4}$, or the quarter root of its mass (the larger the mass of the organism, the slower its embryonic growth, but as mass increases, embryonic growth differences decrease). These quarter-power scalings are present throughout all the living kingdoms. The geometrical details of why a fractal network does involve quarter powers as the scaling factor are complex, but now well understood (in essence, fractal geometry is 4 dimensional). Significantly, the morphological and physiological details that characterize the various classes of organisms turn out to be immaterial. The scaling laws are strictly invariant at a suitable, quite abstract, level of analysis. In the words of West, Brown, and Enquist: 'the predicted scaling properties do not depend on most details of system design, including the exact branching pattern, provided it has a fractal structure' (p. 126). (see also Uriagereka, 1998)

14.2.2 Near-perfect Foraging Strategies

In ethology, as rightly stressed by Hauser *et al*. (2002), for quite some time it has been acknowledged that, in several species, complex foraging strategies turn out to be optimal (Stephens and Krebs, 1986). In general, the animal often adopts strategies that coincide with the best solutions painstakingly discovered also by means of massive computer simulations, solving systems of differential equations under constraints. It is hard to decide whether the explanation of such perfection resides in computational-representational abilities of heretofore unsuspected refinement, or in highly adaptive hardwired dispositions selected over the eons. Be it as it may, NS turns out not to be the only known instance of perfection in biological cognition. The suggestion that NS may have arisen out of a further refinement of such cognitive systems is tentatively being offered by these authors, with some plausibility.

14.2.3 Why (Narrow) Syntax May be "Perfect"

Let's succinctly reconstruct the reasons that have motivated Chomsky's hypothesis that FLN is perfect. The so-called poverty of the stimulus argument (POSA) has been pivotal to the development of generative grammar. Language acquisition, in spite of the extraordinary complexities of language and of poor linguistic stimuli, suggested not just general innatism as a hypothesis, but a kind of unbounded innatism at that. No rule of Universal Grammar was, if well supported theoretically and empirically, too abstract to be attributed to the speaker-hearer's innate knowledge of language; no derivation too elaborate to be computationally out of reach of the mental routines language consists of. Needless to say, that does not tell us much about how the putative innate mechanisms got to be what linguists think they are, in the process raising questions about verifying the plausibility of specific innatist claims vis-à-vis one another. As generative grammar developed, the theory unified under a small set of more abstract rules (later called principles) the variety of contingent and *ad hoc* rules posited by earlier theories in the tradition of structuralism and its Constituent Analysis, as well as classical grammars studying "linguistic constructions". The guiding criterion in this unification has always been never to accept an account that posits distinct or overlapping transparent rules, even if descriptively adequate, when an explanation is available which posits some abstract mechanism which the relevant rules are particular sub-cases of, or deductive consequences of. Inevitably as a result, the core principles of UG have been many steps removed from standard empirical linguistic data. These steps are quintessentially deductive and a corresponding capacity to unconsciously handle these principles and the ensuing derivations and representations is attributed to the speaker-hearer's tacit knowledge of language.

In the nineteen eighties, Chomsky and his associates brought this explanatory strategy to greater extremes: syntax proper was then proposed to consist only of very few, very abstract, computational procedures, and everything else was reassigned to satellite systems (a phonatory-motor-perceptual system, PS, and a conceptual-interpretive system, CS). The rich and subtle phenomenology of linguistic expressions, across all languages, is in this view no more the object of syntactic theory proper, but the result of the interaction between this central abstract system (NS) and the more or less contingent constraints imposed by the systems at the interface. Knowledge of language, still a specific domain of inquiry and a proprietary capacity of our species, turns out to be accordingly decomposed. The ultra-minimal NS system, in itself constrained only by virtually conceptually necessary properties of any computational system, has every reason to operate in an optimal mode. For example, natural conditions of efficient computation suggest that global processes of the sort illustrated in (2), section **14.0.4**, be broken down into smaller computational steps, thus predicting conditions of cyclicity. (See Uriagereka, 1998, chapter 5, for several other instances.)

14.3 A 'Tri-partite' Evolutionary Story

The evolution of the faculty of language in the broad sense (FLB) is now in principle decomposed into three stories, one for each of the components, NS, PS and CS, and of course the way they turn out to be interconnected. These three biological units may have had quite distinct evolutionary origins, presumably only NS being uniquely human.

14.3.1 PS

The child acquires effortlessly, very early (prior to her third year), and with only quite marginal rates of error, the elaborate morphology of her mother language (Pinker, 2000; Spencer and Zwicky, 1998; Tesan and Thornton, 2003). Some evidence suggests that this capacity may be under the control of very few specific genes, perhaps only one (FOXP2, see below). Such ease and precocity is not uniform across linguistic capacities. As we show in the sub-section below, other linguistic tasks that at an abstract (or perhaps better said "disembodied") level look easier and more severely constrained are not fully mastered until 8-9 years of age. The acquisition of the morpho-lexical system is also mastered early on. From 1 year of age until about age 6, the child acquires, on average, one new item for every waking hour. Biological evidence here is mostly indirect, from specific pathologies (anomia and category-specific semantic deficits (since McCarthy and Warrington, 1988)), and from the extreme slowness with which other primate species learn a handful of new words, even under intensive training. It seems plausible, nonetheless, to attribute this capacity to a genetic predisposition, possibly under the governance of the same genes as morphology. The early identification of these units (morphemes, words, etc.) in the flow of speech, and their subsequent memorization, seem to exploit statistical analyzers of a kind that are also present in other species and in other cognitive domains in humans. However in the case of human language, tacit knowledge of quite abstract, specific, and almost entirely parameterized morpho-phonological internal structures must also be mobilized. Finally, intonation, prosody and emphasis – supra-segmental components of communication by speech that are modulated analogically, rather than discretely – are also part of the picture and have non-negligible analogs in other species. Ever since the pioneering studies of Paul Broca and Carl Wernicke, it is well known that these components may remain intact even in cases of severe lexico-syntactic deficits (confabulatory paraphasia and jargon aphasia (Brain and Bannister, 1992; Broca, 1878; Wernicke, 1874)) It is prima facie plausible to conjecture a genetic disposition also for them.

14.3.2 CS

The acquisition of semantics has only recently been seriously looked at, among other things because reliable testing is extremely difficult with very young children (though see Crain and Thornton (1998) for very ingenious methodologies). A general consensus as to whether CS conditions are acquired early or late has not emerged yet, although the most well-known instance of putative late acquisition of a grammatical principle is arguably of this sort. Without attempting to take a position on this, consider the basic facts:

(7) a. John knows [he is late]

b. [John knows him]

It is easy to see that whereas *John* and the pronoun in (7a) can refer to the same individual, this is not possible in (7b). The phenomenon is referred to as (local) "obviation", has been shown to be universal across languages, and is customarily explained in terms of a so-called Principle B responsible for preventing co-reference between pronouns and (in essence) their corresponding subject when both elements are clause-mates (basically, in the same sentence). Principle B thus eliminates a possible (in the abstract) interpretation of (7b). Curiously, Chien and Wexler (1990) have shown that children allow co-reference in precisely these circumstances, well into the last years of their first decade. It is not, incidentally, as if children do not have any version of local-obviation, and thus presumably of Principle B as well. Thus, the same children who allow the impossible interpretation of (7b) disallow a similar interpretation for (8b):

(8) a. No one knows [he is late]

b. [No one knows him]

When the pronoun's antecedent is a quantifier like *no one*, even very young children disallow the impossible, co-referent reading (in (8b), "for no x, x knows x"). This suggests that a property of CS in a broad sense is at stake in the children's failure to rule out (7b) (see Thornton and Wexler, 1999 for a detailed discussion of the phenomenon). It is too early to tell, however, whether this well-known result is the norm or the exception in CS, and thus whether this component in general (if it is a unified component to start with) is in place as early as PS clearly is, or matures instead in some non-trivial fashion.

14.3.3 PS Meets NS

The current Minimalist program suggests that all NS does is to create new objects out of pre-existing morpho-lexical units. These new objects are the most elementary: sets. In the simplest instance, the system takes A and B and creates (by the operation we referred to as "Merge" above) the set {A, B}, in which A and B remain distinct. These operations are recursive, and the output of one can be the input to the next, thus resulting in a kind of Calder mobile. The interface with PS imposes that these hierarchical constructs be linearized: whereas the objects assembled by Merge are (at least) two-dimensional, speech is one-dimensional. Therefore, all the objects delivered to the phonetic system by NS, no matter how multi-layered they may be, must be submitted to a relation of order. Since linearity would flatten hierarchical relations beyond recovery, thus delivering to CS un-interpretable gibberish, one of two properties apply: (a) Linear order unambiguously reflects hierarchical structure (Kayne, 1994) (for a different version, see Moro, 2000), and/or (b) some marker that PS can detect (e.g. an agreement or Case marker) is attached to one item in the string, and it corresponds, in ways that CS can process, to a marker attached to another item in the string (Uriagereka, 2002:chapter 3). This much suffices to send to CS specific constructs that it can interpret. Assume that PS can avail itself of a rich array of markers (features), liberally provided by the morpho-syntactic component. In this sense, morphology is like a virus or a transposable element: it has a tendency to attach itself to, and proliferate across, items, if left un-checked. The morpho-lexical repertoire and PS, unlike NS, are not designed optimally, and tolerate redundancy, arguably for reasons that we return to in section **14.5**. The morpho-lexical component "feeds" to NS some unnecessary material which NS, because of its maximum-efficiency design, gets rid of as soon as possible, thus implementing in the system the cyclicity that we alluded to in the previous section. In a nutshell, features that CS can “understand” (interpretable features) are transferred to this component, while features that CS has no use for (un-interpretable features) are parasitic (in our sense “viral”) on the first, and are deleted before they reach CS. A topic under much current study is whether (observable) cyclic effects on interpretable features emerge as a side effect of checking un-interpretable ones, or some other condition on the system imposes computation by phases (Boeckx, 2002, to appear; Carnie, 2003; Chomsky, 2000; 2001; Collins, forthcoming; Uriagereka, 2002; Epstein and Seely, 2003, forthcoming) Either way, languages vary in restricted ways (parametrically) as to what NS delivers to PS, and possibly as to what NS delivers to CS.

14.3.4 NS Meets CS

The conceptual-intentional system of humans, though itself demonstrably prone to intrinsic and rather peculiar limitations (Kahneman *et al*., 1982; Kahneman and Tversky, 2000; Piattelli-Palmarini, 1994) is by and large an awesome machinery. It may, therefore, appear strange that it should impose limits upon its interface with NS. Before minimalism, intrinsic semantic limitations (impossible lexical meanings, structural ambiguities, multiple embeddings, garden-path sentences, etc.) were attributed either to limitations on performance, or to the surfacing of intrinsic lexico-syntactic constraints. In minimalism, however, because of the assumed perfection of NS, only *interface* constraints can be posited. As we said earlier, CS is bound to assign systematically and deterministically a fixed (set of) interpretation(s) to each syntactic structure that is delivered to it by NS, via PS. The productive isolation, in the vast domain of semantics generally intended, of context-independent systematic effects of linguistic form on meaning (in the characterization of James Higginbotham (1992)) has engendered a successful scientific enterprise: the semantics of natural languages. This scientific discipline carves for itself, out of the vast and multifarious array of intellectual abilities that humans can deploy, a neat field of inquiry, intimately conversant with syntactic theory, formal logic, general semantics and the theory of the lexicon. Its central object is not so much meaning per se, but rather the speaker-hearer’s “knowledge of meaning” (Heim and Kratzer, 1998; Higginbotham, 1985; 1989; Larson and Segal, 1995). How this knowledge may have evolved, once an adaptationist account has been questioned, is far from clear.

Of course, many animals, and not just the “higher” primates, arguably have mental representations of some sort, are sensitive to causal relations, regularities in the world, inter-personal relations, even social status, and are capable of learning (for a comprehensive analysis, see Hauser (1996)). All this, in the absence of language. Assuming NS materialized because of distinct evolutionary vicissitudes (see the next section for a conjecture), do we have reasons to believe that, once it is “plugged into” (roughly) the conceptual-intentional apparatus of an ape, we get CS (knowledge of meaning) as we experience it? Or a “smaller” CS (some knowledge of some meanings)? That would require better data and a careful analysis. As Hauser, Chomsky and Fitch specify, we also need, at a minimum, unprecedented imitational capacities in the domain of lexical acquisition, and the accompanying aptitudes to “lock” (à la Fodor (Fodor, 1998a)) morpho-lexical sounds (or cheremes in the case of sign languages, or plastic tokens, as used in experiments on primates) “onto” salient properties of objects and events in the surrounding world. A charitable disposition towards data from trained chimps may make acceptable the idea that the difference between a chimp and a child, in this domain, is rather quantitative (though huge) than qualitative. Limited mastery of the set-subset relations (part of, inclusion, etc.) and of something akin to logical consequence, appears to be attainable by some apes. Their capacity to attribute states of mind and states of knowledge to conspecifics and trainers is controversial (Hauser *et al.*, 2002; Povinelli, 2000; Premack and Woodruff, 1978), but we may want, here too, to make a charitable stand.)

14.4 A Conjecture on the Evolution of (Narrow) Syntax

We have seen what the field of linguistics takes to be irreversible results in the study of language and what the dominant paradigm has to say about the most plausible way of relating these facts in a theoretical fashion. We have discussed the most basic notions of the theory of evolution as well as what the current wisdom is with regards to how these notions are to be complemented with more contemporary tools from present understanding of complex dynamic systems, among others. Putting these ideas together, we have begun to sketch what we take to be the boundary conditions of any evolutionary story pertaining to human language. Now we would like to be more precise. We should say from the outset that, of course, we could be wrong in our account; but we strongly feel that this is the right *kind* of account.

14.4.1 The Virus Theory

We have likened morphology to a virus, or a transposable element (TE), but we have not discussed how plausible this hypothesis is, particularly when we assume with Chomsky (Chomsky, 1995) that transformational processes (involving “displacement” in the sense in section **14.0.3**) implement a kind of “immunization” against uninterpretable morphology. The idea is to motivate transformational applications, so that they never apply idly. Thus, movement transformations are triggered by the need to eliminate (technically *check*) uninterpretable features. For instance:

(9) a. It seems [Jack is the leader of this group]

b. Jack seems [__ to be the leader of this group]

c. *It seems [Jack to be the leader of this group]

(9a) and (9b) are good paraphrases, which suggests the two sentences have relevantly identical underlying structures. However, their superficial differences are dramatic: in (9a) the subject is a non-referential *it*, whereas in (9b) the subject is *Jack*. Correspondingly, in the embedded clause the subject is *Jack* in (9a), whereas an unpronounced gap is in (9b). That suggests that *Jack* in (9b) has been displaced from the embedded to the matrix subject position, as follows:

(10) a. __ seems [Jack to be the leader of this group]

b. Jack seems [__ to be the leader of this group]

Let’s represent (10a) as in (11):

....................…
:   :
(11) [__ [**Tense-agr** seem [[**Jack**] [to be ...]]]]
TARGET   SOURCE

In this instance the crucial feature in the target (of movement) are agreement features in Tense (T), and the source of the movement is *Jack*, which can appropriately check those uninterpretable features in terms of its own interpretable ones. In the process, the source element becomes accessible to the computation by way of Case valuation, which the target renders. But this process is only half the story. The other half pertains to why Uriagereka (1998) termed these features ‘viral’. In 1995, Chomsky implemented cyclicity effects in the system by way of stipulating that a process along the lines of (11) must take place *immediately* after the computational system detects the presence of an uninterpretable feature. In other words, Chomsky disallowed the possibility of facing a structure like (11) and not doing anything to eliminate the uninterpretable feature in T until later in the derivation, when the corresponding TP is embedded under some other element. One can liken this immediacy to the sort of response the immune system has upon the recognition of a virus, or a bacterium (but the latter are of no relevance here, because only viruses can be integrated in the genome and then be transmitted vertically to the next generation). Basically put, the computational system, in this view, detects an alien element (the uninterpretable feature) and it puts its resources to play in order to eliminate that element.

Apart from accounting for the derivational cycle (recall from section **14.0.4**) through his interesting mechanism, Chomsky wanted to correlate the somewhat puzzling phenomena of morphology (section **14.0.5**) and transformations (section **14.0.3**). But Chomsky had a third mystery that he thought could be correlated with the previous two: core variation in the syntactic system (section **14.0.6**). We know that languages vary superficially in their morphological details (overt agreement paradigms, Case specifications, etc.). If it is this sort of morphology, termed by Chomsky “strong”, that is at the core of uninterpretability and its transformational elimination, then it stands to reason that overt displacement would be a side effect of strong morphology. Languages clearly differ on whether they tolerate given transformational processes in particular domains. Consider for instance “verb movement” in English and in Spanish, as in (12):

(12) a. [Who [has [John [t [seen t]]]]]? (cf. *Who John has seen t?)

^   ^_ _ _ _ _/   /
|_ _ _ _ _ _ _ _ _ _ _ /

```
b. ¿[A quién [vio [Pedro [t [ t   t]]]]] (cf. *¿A quién Pedro vio?)
      to whom saw Pedro /^  /  /
             ^      ^_ _ _ _ _/  |/   /
              |_ _ _ _ _ _ _ _ _ _/
```

Whereas in (modern) English only the top auxiliary verb is displaced (12a), in Spanish the main verb is (12b). The verb fronted in these contexts is whichever one sits in the inflectional head of TP. In English that is the auxiliary (or a corresponding dummy *do*), whereas in Spanish it is the main verb. Why? The correlation was noted by Emonds (Emonds, 1978): languages with a "strong" inflectional morphology in TP, such as Spanish, require the main verb to move to T in order to check it, whereas languages with a "weak" inflectional morphology in TP, such as English, only allow the auxiliary verb in T. Indeed, older forms of English clearly had richer morphological paradigms in the verbal system, and allowed a variant of the Spanish (12b) (*Whom seist thou?)* It would be extremely interesting if, more generally, the core domains involving given transformations (e.g. verb movement) generally involve morphology in some way, and it is contingent, strong or viral, morphology which is the culprit of ostensive transformations, thus possible constructs only in languages with the relevant morphological traits.

14.4.2 Other Consequences of (Real) Viral Interactions

Apart from providing an interesting correlation (morphology, transformations, variation), our virus theory has an independent plausibility, from an evolutionary perspective. The issue is how to evolve NS in our species, very recently and (as we see in section **14.5**) arguably very fast. Although a genetic change is very likely implicated, it is hard to imagine that this could be the whole story, among other things because genetic changes tend to be either too specific (if the gene is responsible for a single trait) or too general (if the gene is a master-control, one responsible for the regulation of other genes). The evolution of an entire mechanism (such as NS) which establishes one or more interfaces is most likely epigenetic in nature, and viral interactions, generally understood, provide the right level of complexity. Viruses are exquisitely species- and tissue-specific, they code for structural proteins and can infect an entire population, and importantly for our purposes, unlike bacteria or other parasites, they can integrate into a genome. Unlike maliciously built computational viruses, biological viruses don't have a purpose, thus may a priori result in a variety of consequences for an organism. Granted, the normal result is a more or less major disruption of the organism's functions or structure, due to the rapid multiplication of the infecting virus at the expenses of the host's own machinery, but this is not inevitable, and in principle a virus may sometimes be integrated stably, and inheritably, into the genome of its host. In fact, complex co-evolutions between viruses and hosts are known to have happened,[3] furthermore with viable structural changes in

[3] An example brought to our attention by Donata Vercelli is reported by Moore *et al.* (1990) and Hsu *et al.* (1990). These authors found that a viral protein from the Epstein-Barr virus (EBF), called BCRF1 shows high homology with a cellular protein (called Interleukin-10 – or IL-10). IL-10 is a member of a wider class of proteins, called cytokines, released by the immune system of mammals (humans included), which help regulate the immune response. Among its many effects, IL-10 inhibits the synthesis of interferon gamma, a cytokine with

the host, which in addition get transmitted to its offspring. (See the RAG example in section **14.1.3** above).

In that respect, an illuminating analogy between the structure of nucleic acids and the structure of language suggests the concrete possibility that some RNA secondary structures might have just that sort of origin. This is important because the modeling of nucleic acids indeed shares important formal properties with the modeling of linguistic systems. For instance, nucleic acids are constructed over the basic "vocabulary" of four bases, which string themselves in various ways. But groupings exist as well, which have to be modeled in terms of complex formal languages. For example, a folded RNA secondary structure called a "stem loop" entails pairing between nucleotide bases that are at a distance from each other in the primary sequence. While the primary sequence can be modeled in terms of finite-state automata, the stem loop involves "nested dependencies", which require a context-free grammar modeling, as Searls (2002) shows. Moreover, Searls also observes how non-orthodox secondary structures called "pseudoknots" (pairs of stem-loop elements in which part of one stem resides within the loop of the other) induce "cross-serial dependencies" in the resulting base pairings. This cannot be expressed in context-free terms, as it requires to look into the derivational history of the ensuing structure. That is, we find a hierarchy as in (13a), which is entirely analogous to the canonical Chomsky hierarchy for grammars, and in particular its linguistic realization in (13b):

(13) a. nucleotide strings > stem loops > pseudoknots
(pairings of nucleotide strings) (pairings of stem loops)

b. word strings > context-free phrases > context-sensitive transformed structures
(sets of word strings) (sets of phrases)

Could syntactic transformations have an abstractly similar origin, either as a result of an actual biological viruses, or possibly some computational analogue?[4]

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well known antiviral properties. The viral protein (BCRF1) and the cellular protein (IL-10) are 70% homologous, and they were, therefore, expected to possess very similar activities. The experiment proved that this was, indeed, the case: After it was cloned and expressed, BCFR1 was capable of inhibiting the synthesis of interferon gamma in human and in mouse cells, just like IL-10 does. According to these authors, BCRF1 is a processed viral homolog of the cellular IL-10 gene and, since both possess analogous functional activities, BCRF1 could participate in the interaction of the EB virus with the host's immune system, inhibiting the anti-viral activity of interferon-gamma and thus favoring the early generation and outgrowth of EBV-infected cells. The authors suggest that EBV may have "exploited the biological activity of the product of a captured cytokine gene to manipulate the immune response against virally infected cells, thereby promoting survival of the virus…. the expression of captured genes encoding immuno-regulatory proteins could be a mechanism used by other viruses … in their interaction with the host's immune system."

[4] It is worth emphasizing in this respect that a small new field of computer science is devoted to exploring the computational modeling of immune systems (so-called artificial immune systems). See in this respect Dasgupta (1999).

14.4.3 Towards a Model for the Evolution of FLN

Hauser *et al*. (2002) provide us some clues as to what they think may be involved in the evolution of NS. They ask us to suppose that the interface systems are given, and the innovation yielding the faculty of language was the evolution of a linking computational system. Furthermore, they remind us of the possibility (reviewed in section **14.2**) of "perfection" with NS, stating in particular that many of the details of language

> . . . may represent by-products of this solution, generated automatically by neural/computational constraints and the structure of FLB - components that lie outside of FLN. Even novel capacities such as recursion are implemented in the same type of neural tissue as the rest of the brain and are thus constrained by biophysical, developmental, and computational factors shared with other vertebrates.

That last statement is a favorite of Chomsky's theorizing with regards to linguistic evolution. In its skepticism towards simplistic adaptationism, it goes back to D'Arcy Thompson's (1917/1992) monumental work *On Growth and Form*, the basis for modern computational biology through Alan Turing's (1952/1992) work on the topic. The idea is that structural details of NS may result from such preexisting constraints, "rather than from direct shaping by natural selection targeted specifically at communication. . . [They] are not, strictly speaking, adaptations at all". If so, we may expect to find similar systems in different (i.e., non-communicative) domains (Chomsky, Hauser and Fitch specifically mention foraging as discussed in section **14.2**, as well as navigation systems, where comparable "search problems" arise). Then they go on to make the point that if recursion evolved to solve computational problems such as navigation, number quantification, or social relationships, then it is possible that other animals have such abilities. Which raises several questions:

> Why did humans, but no other animal, take the power of recursion to create an open-ended and limitless system of communication? Why does our system of recursion operate over a broader range of elements or inputs (e.g., numbers, words) than other animals? One possibility is that recursion in animals represents a modular system designed for a particular function (e.g., navigation) and impenetrable with respect to other systems. During evolution, the modular and highly domain-specific system of recursion may have become penetrable and domain-general. . . *This change from domain-specific to domain-general may have been guided by particular selective pressures . . . or as a consequence (by-product) of other kinds of neural reorganization*. [Our emphasis]

There is an "immune syntax" scenario one can present as a modest contribution to the study of this intriguing possibility. Suppose that, at some point, humans only had some formal system at the second level in the Chomsky hierarchy in (13b) (phrase-structure), perhaps a form of proto-language in the sense of Bickerton (1990) or maybe even a system unrelated to symbolic communication. NS in the sense that concerns most syntacticians would not have arisen yet. Then a major mind/brain reorganization would have taken place, which one hopes the detection of the morphological virus may be related to. The technical question is: Supposing we have an organized elementary syntactic structure, and furthermore an alien element which in some sense does not belong, what can the host do in order to eliminate it? First of all, it must *detect* the intruder. This is no trivial task in a set of mechanisms which, by all accounts, has virtually no holistic characteristics. One possibility is for the host to detect the intruder on the basis of not being able to integrate it semantically (assuming a general strategy of Full Interpretation in the sense of section **14.0.9**). Next, there has to be some sort of "immune response", whereby the intruder is somehow eliminated. The issue here is "who" eliminates the virus, and "how". One must bear in mind that all of this has to be done with systemic resources. One of the few simple ways that a set of mechanisms of the assumed complexity would have of proceeding with the immunization task would be to *match* the virus element in categorial type. This is a bit of presupposed structure (non-terminal symbols, i.e., phrasal nodes) in phrase-structure grammars. It is as if a morphological "antigen" were detected and eliminated by a syntactic "antibody". As to how the elimination proceeds, one has to allow the set of mechanisms the ability to delete the virus matched by the antibody, under a strong version of the match: full categorial *identity*. In turn, if the host behaves as immune systems do, it should keep a *memory* of the process (after a single exposure to a virus, immune cells memorize the intruder and provide resistance for life). Presumably, then, in the presence of detected virus *v* of category X, the host will *systematically* respond with matching antibody category X, and the elimination of *v* under complete featural identity with the particular categorial values that X happens to exhibit. Otherwise the relevant host (derivation) would die (terminate). This sort of response, which forces the system into an antigen-antibody dependency that only a context-sensitive system can model (one where the derivational history can be accessed, that is at the highest level of the hierarchy in (13b)) amounts to the fixation of a morpho-syntactic parameter. The structural situation sketched in (11), repeated now as (14), would be rationalized as in (15):

(14) a. [__ [**T-agr** seem [**[Jack]** [to be ...]]]]
TARGET SOURCE

(15)
a. Virus (☼) detection: [T-[☼agr] [seem [[Jack] [to be ...]]]]

b. Search for categorial match with antibody (⬡) [T-[☼agr $_D$] [seem [[$_{DP}$ Jack⬡] [to be ...]]]]

c. Eliminate virus under categorical identity [T-[agr $_D$] [seem [[$_{DP}$ Jack ⬡] [to be ...]]]]
D values = DP values

d. Systematize the sequence <(a), (b), (c)> as typical of the language.

As a result of the transformational process, there is a demonstrable sense in which the ensuing formal object is more complex than it was prior to the "immunization", in that the basic "tree" relations are warped. This can be illustrated as in Figure II:

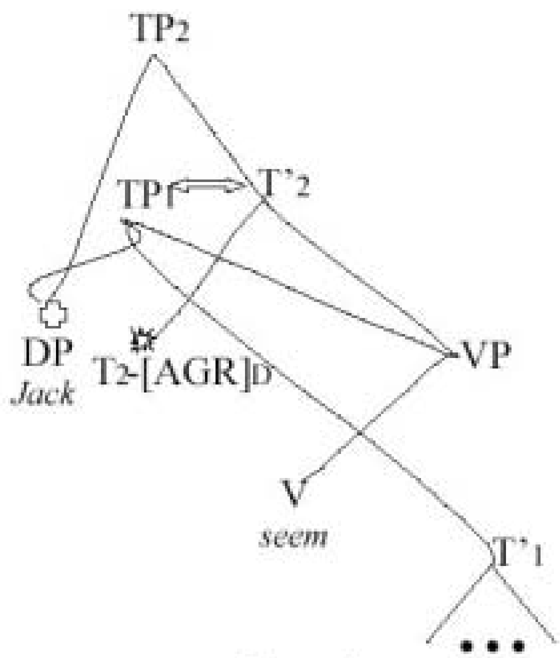

Figure II

The warped object resulting from associating the antibody DP (a Determiner phrase, that is any argumental nominal) to the T with a viral feature which happens to be of the D sort (agreement in person/number) creates new local relations. In particular, the viral antigen-antibody relation establishes a "chain". Formally, a chain is a set of phrase-markers, defined over the contexts of a transformation. For instance, TP_1 in Figure II (the mother of the *Jack* node) establishes the context for the lower link in the chain, while the T'_2 in Figure II (the mother of the T_2 node hosting the antigen) establishes the context for the higher link in the chain. The chain linking the two relevant sites for the immunization is {{*Jack*, T'_2 }, {*Jack*, TP_1}}, or {T'_2, TP_1} if we factor out *Jack*. This chain is indicated as a hyper-link $\Leftrightarrow$ in Figure II. A chain is analogous to secondary structuring in nucleic acids, that is, the establishment (through something like a pseudo-knot) of relations between bases further apart in the linear sequence: relations other than the most elementary pairings which primary structure yields. Just as RNA secondary structures have numerous consequences (through the ability of information sharing of a sort which, without the pseudo-knot, would be too long-distance to be viable) so too chains have consequences. Arguably the most interesting is binary quantification.

For instance, something like the semantics for a sentence like (16) cannot be coded in standard predicate calculus:

(16) Most people were arrested.

Barwise and Cooper (1981) show how there is no way of expressing the relevant thought in terms of predicate-argument relations, elementary quantification, and boolean relations. The semantics of (16) must involve *restricted* or binary quantification, establishing a group of people and a group of arrested individuals, intersecting the two, and stipulating that the ensuing intersection be larger than some proportion (more than half) of the group of people (recall from section **14.0.10**, where it was shown how the arguments of natural language quantifiers have to be syntactically ordered, what we referred to as 'conservativity'). Restricted quantification has emerged as a key feature in the semantics of natural languages in recent years (Heim and Kratzer, 1998; Herburger, 2000; Larson and Segal, 1995; Pietroski, 2002) Observe the relevant phrase-marker prior to any transformation, as in Figure IIIa below. While the NP *people* is in construction with determiner *most* (as it should be, since we want *people* to constitute the "restriction" of *most*, from which we interpret one of the relevant groups in the quantification), the VP from which we can interpret a group of leavers (the other basic element in the computation of the quantifier) is clearly not in construction with *most*. Next observe the phrase-marker after it is warped by an immunization/transformation, as in Figure IIIb. Now a chain {T', VP} is established, and furthermore the displaced DP "re-merges" to T'. It is thus reasonable to expect that DP is in construction with the {T', VP} chain, and as a result can allow a semantic relation between the D head *most* and the (tensed) contents of the VP, denoting "those who were arrested". At this point, the possibility for a quantification is no more complex than a similar situation arising in transitive verbs with two arguments within the verb phrase. The "pseudoknot" in Figure IIIb has opened a whole new domain of information. Moreover, it has done so rather blindly and mechanically, not through a smart procedure which introduces a device into NS solely for interpretive purposes (thus questioning the autonomy of syntax). In the present view, the complex object in Figure IIIb is simply a rearrangement of more elementary lexical features, nothing more holistic than that.[5]

[5] If this kind of syntactic "inclusiveness" is satisfied, then the only modes of interpretation must be local syntactic relations (minimal extensions of the notion "sister" to a word). This presupposes a certain dual nature of semantic interpretation. Pre-warped structures represent basic Merge, which language uses to express thematic relations of the agent/patient sort. In turn, warped structures add a further dimension: the scope of quantifiers and related notions (e.g. the contextual confinement of these elements). Chains in the sense above trace the derivational history of phrase-markers which undergo the relevant warpings. The chain is not so much the warped object as the process that carries it from the flat stage to the warped one. The moved item thus occurs, as it were, in two significant places in (derivational) time: where it originates and in the object that ensues after it moves. Each of these occurrences is employed by the system in interpretive ways.

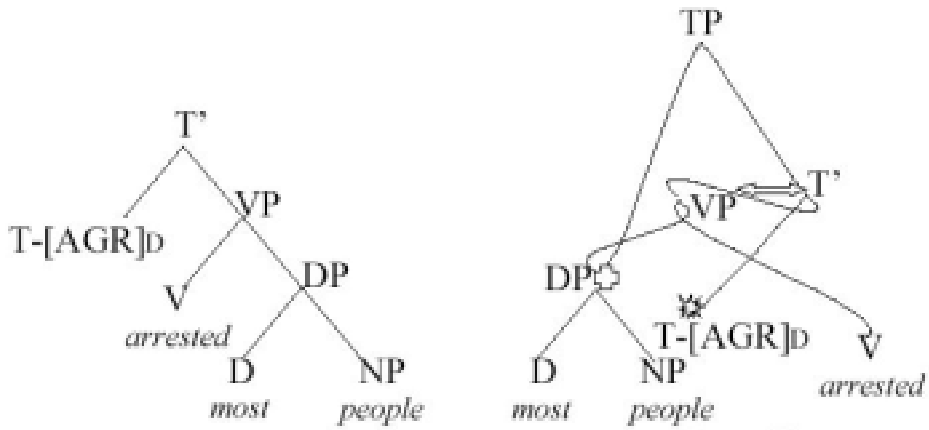

Figure IIIa Figure IIIb

The above result is topological. After the immunization takes place, a new topology emerges, and the result lends itself to otherwise impossible interpretations. We realize that, without a worked out theory pertaining to the nature and plausibility of the morphological "virus", this conjecture is essentially metaphorical. We address this matter in the section **14.5**, obviously in a tentative way. Nonetheless, we think our metaphor is productive and worth pursuing to its several interesting consequences. Indeed, there are reasons to believe that it may be more than just a metaphor, but we can only sketch the form of that argument now.

14.4.4 From Sub-symbolic to Symbolic

One more point is worth emphasizing, concerning the labels involved in the immunization. This refers specifically to steps (15b) and (15c) above, the search for an antibody in terms of categorial match and the elimination of the virus when there is full categorial identity (identical feature values in the category). All of that talk is "representational", in more or less the philosophical sense, which may be relevant with respect to the symbolic nature of human language. The various levels of the Chomsky hierarchy in (13b) above are not equally "symbolic". Finite state automata create lists of anything, not just symbols (one could thus order, say, the different pages of this article). Phrase-structure grammars already need symbols of sorts, in that they must code abstract non-terminal elements to group terminals in characteristic fashion. However, these symbolic elements are, as it were, grammar-internal, mere grammatical states to chunk sets of terminal items appropriately, regardless of whether these items are themselves symbols or, again, pages on a book, perhaps organized into (abstract) chapters. Matters change drastically when one goes to the grammatical levels which are sensitive to context. Context sensitivity in these circumstances just means having access to derivational history, thus implies some sort of memory of what went on. But memory is representational (in the philosophical sense). Thus the question emerges of whether this representational character presupposed by transformational grammars could have had anything to do with the representational use of language symbols, in evolution. In particular, might this have resulted in the "penetrability" that Hauser, Chomsky and Fitch were seeking in their evolutionary scenario, allowing cross-modular talk between elements internal to some mental system (whatever that was) and the possibility of applying these elements in other modules as representational devices?

We do not know the ultimate answer to that question, but one should keep in mind that so-called "proto-language" as such, prior to the momentous evolution that we are seeking to understand, may have been more of a thought procedure –not unlike those presumably relevant for navigation or foraging in other species– than a bona fide representational system for communication. It may have been quite sophisticated, but also solipsistic, at least to some extent. Communication as such (certainly very robust across species prior to the emergence of *homo sapiens sapiens*), instead of through bona fide symbolic understanding in the usual sense, may have been induced merely by imitation of behavioral patterns, much as associationist theories of various sorts expected (wrongly) modern human language to work. Note in particular that a system with those characteristics would have had virtually no *communicative* use for recursivity, even if it may have encoded it (phrase-structure systems in principle do), and may even have used it for modular purposes having to do with elaborate, though irrelevant, thought chains. At the very least, nothing that we know of in the relevant literature allows us to eliminate this interesting possibility, and it certainly is the one that makes the fewest assumptions about the nature of "proto-language". A similar point can be raised about the fact that, although it is very likely that "proto-language" was an oral system (given what we know about the larynx of other hominids), this does not entail that it served for communication, let alone of a "symbolic" sort. Many species have noise-emitting devices that do not serve any obvious communicative purposes, although of course the resulting noise can be used by other individuals, of the same or different species, to infer all sorts of things about the noise source. The point is, the scientific method cautions us to be conservative in our estimations about our most extraordinary claims (and finding "symbols" in nature is as extraordinary as it gets) in the absence of extraordinary evidence going for them. The use of transformational devices to eliminate a morphological virus would count as rather strong, if indirect, evidence for symbolic systems. Prior to that, it's anybody's guess.

14.5 A Suggestion for Going Beyond the Metaphor

What we have presented above is the logic of a proposal, based on properties of immune responses to viral intruders. One possibility is that precisely something along those lines took place in the course of human linguistic evolution (some virus had the desired effect), and it remains to be seen whether this particular story can be ascertained beyond general plausibility considerations.[6] A second possibility is that, although there may have been no real virus that infected human populations, in effect a computational analogue emerged, with overall

[6] A further interesting similarity between the action of viruses and the working of neurons under certain conditions is evidenced in Dyer *et al.* (2003). Wayne Sossin and collaborators (at the Montreal Neurological Institute) have demonstrated that normal nerve cells in the sea slug Aplysia can use an internal ribosome entry site (IRES), something that is normally and characteristically exploited by viruses, to produce large quantities of protein under physiological conditions. This finding is presented as having possible important implications for understanding the learning and memory processes in the brain.

responses by minds (at the relevant level of abstraction) of the sort witnessed at more basic biological levels. We cannot go into the first possibility at this point, but we will be examining it closely in forthcoming work. The second possibility can be analyzed on the basis of certain conjectures made by Chomsky on the nature of morphology within the linguistic system, and its putative correlation with linguistic variation and ostensive transformations. We explore that route mainly for concreteness.

We have linked immunological memory with, in effect, (proto-)parameter setting in the linguistic sense: structures where the virus is present result in relevant immunizations (or otherwise crash), but presumably the virus is not present just everywhere, thus resulting in variation if different languages differ in this respect. Is it possible, more generally, to tie up the evolutionary scenario to linguistic variation? The question pertains to the origin of morphology, which sets the logic of the "immune syntax" in motion. The fact that variation exists, in itself, is a strong argument for the recent evolution of FLN. It would appear that variation in something which is used (even if partially) for communication purposes should have been weeded out by evolution, assuming it doesn't aid communication. However, if FLN has emerged very recently and core variation is tied up to it, evolution hasn't had the time to eliminate it. (Ironically, and tragically, at present rates of language extinction, this "goal" may be achievable within our very own civilization.)

14.5.1 A Language Gene

Lai *et al*. (2001) have found a gene, FOXP2, which seems to be involved in speech. The regulating gene, located on chromosome 7, was discovered while studying a family most of whose members had troubles, at least, controlling their lips and tongue and forming words. Apparently, FOXP2 is responsible for that linguistic breakdown; in particular, the family in question presents a mutation in the gene which disrupts the DNA-binding area of the protein it specifies. Even more recently, Enard *et al*. (2002) studied FOXP2's evolutionary history by comparing versions of the gene in various primates and mice. FOXP2 has remained essentially unaltered during mammalian evolution, but it changed in humans (affecting at two sites the structure of its protein) after the hominid line of descent had split off from the closely related chimpanzee one. The changes in the gene (which alter the protein shape and its functional role) are universal in human populations. Enard *et al*. speculate that the changes affected speech articulation, and by measuring the reduced diversity in the DNA section corresponding to the gene (the result of its sweeping through the population) they estimate that the human version of the gene emerged only 120,000 years ago.

Those results are very consistent with others pertaining to the timing of geographical dispersion, offered by comparative genetic studies carried ever since Cann *et al*. (1987), both on mitochondrial DNA and the Y chromosome of people from diverse ethnic backgrounds. This evidence indicates that the world's population can be traced back to a family tree rooted in sub-Saharan Africa less than 200,000 years ago, and a branch leading into the rest of the world somewhere within the last 100,000 years (perhaps even 50,000 or less (Klein, 2003)). If coupled with the FOXP2 dating, these dates present reasonable boundary conditions for the emergence of language as we know it. It is of course unthinkable that a major migration that very rapidly carried the species to the confines of the planet, crossing hundreds of miles over deserts and seas in the process (thus presupposing long-distance navigation), could have been achieved without modern language. Moreover, at the "end" of this exodus in Europe, Australia, Southern Africa and eventually the Americas (much later), a very sophisticated tool-kit and, moreover, art in the full sense of the word, are clearly present, some 40,000 years ago. The species responsible for these wonders has to be representational, hence arguably must have achieved the transformational level in the Chomsky hierarchy (see section **14.4.3**). Could FOXP2 have had anything to do with the birth of morphology? If it did, the rest of the logic would carry creatures with a non-symbolic faculty into its present mode.

14.5.2 A Proto-language?

If the Lai and Enard groups (teams working with Anthony Monaco and Svante Pääbo) are correct, FOXP2 gave humans a significantly improved "phonotactic kit", hence a massively expanded phonetic vocabulary (see Carstairs-McCarthy, 1999, on this general point). Granted, in the present picture, that vocabulary may not have had real symbolic consequence, and would rather be closer to what birds and other mammals (spontaneously) have, or even (perhaps) what some apes can be trained to acquire. One can speculate that, other than signaling for individual or group identifiers, or frozen calls of the sort known to be sophisticated in rhesus macaques (signaling food, predators, or similar basic entities), this "proto-language" allowed for elementary grounded messages, involving indexicals (or names) combined with immediate locations, or even salient characteristics. In other words, and to be concrete, it is legitimate to have expressions of the sort in (17) without a sophisticated symbolic system behind it:

(17) a. Hey, Joe! b. Lion, lion! c. You there, I here.
d. You woman, I man. e. You take food, I hit you.

(17a) and (17b) are just calls, probably even in modern language; that is, there is nothing obviously propositional about these expressions. As Bickerton (1990) rightly emphasizes, something akin to this is typically tried out by speakers of different and essentially unknown languages, when they are contingently forced to communicate nonetheless, or on emergency radio calls, or when shouting at a distance (ship-to-ship without a radio, for instance). Although there could obviously be a propositional analysis of these elements (which presupposes symbolic representation), this is by no means necessary. For example, (17c) could simply invoke vague relations among indexicals, the ultimate "meaning" of the expression left to guess work combined with the pragmatics of when (17c) is uttered (e.g. "you stay there and I here, so we won't have trouble" or "you over there, I over here want your attention", etc.). (17d) invokes categorization of some sort, which is customarily expressed in formal semantics in set-theoretic terms. However, it is known both that this sort of ability, in its most rudimentary form, is not specifically linguistic, and that non-human species are capable of some form of categorizing, based on statistical inferences (Hauser *et al*., 2001). Expressions of the sort in (17e) should be possible in proto-language as well, under the assumption that said statistical regularities can be combined and generalized by intelligent creatures. We arguably have a ground-level sketch of what this proto-language may have looked like by observing actually recorded "sentences" from heavily trained chimpanzees and bonobos. The ones in (18) are examples taken from Terrace *et al*. (1979) famous record on Nim Chimpsky-signed productions:

(18) a. Play me Nim b. Grape eat Nim c. banana eat me Nim

d. Give orange me give eat orange me eat orange give me eat orange give me you

We have no way of knowing whether these expressions were symbolic, but even if they were not (Terrace *et al*'s own conclusion), they constitute complex expressions of whatever sort they are. (17e) above does not seem a priori more cumbersome than (17d), and one may surmise that, in either instance, a sophisticated representational apparatus of the sort formal semantics invokes for regular language is besides the point.

14.5.3 Proto-variation?

The expressions in (17) and (18) pose a dilemma, vis-a-vis FOXP2's putative role in the emergence of modern language. Must facilitating muscle control in the vowel tract, thereby allowing a vocabulary explosion, have an *immediately* good consequence for creatures of Nim Chimpsky's abilities? Every amateur carpenter knows that (too) many sophisticated tools can be dangerous. A limited repertoire of elements corresponding to the limited syntax implied in proto-language may not have been so bad. If one cannot distinguish too many words (trained chimps produce up to a couple of hundred), the chances of getting a garbled message are far fewer. Of course, a trivial vocabulary implies either huge (and possibly many) words or a tiny lexicon (with words the normal size). Enter the new phonetic kit and new expressive possibilities emerge, as (exponentially many) new signals can be coded. This could be a nice step forward –or the potential for trouble. Computational models by Nowak *et al*. (2002) suggest that a few dozen words (to be elementarily associated) is a good threshold for needing more than just list-forming syntax. This is because it is computationally more sound to assume rules for phrasal composition than to keep taxing one's short-term memory by adding new words which make lists in principle longer and more cumbersome. Proto-language may have had more implicit expressive power than a Markovian system, but the system could have been devoid of representational characteristics. If so, it could not have handled in phrasal ways the richer vocabularies that the putative direct consequence of FOXP2 may have had. This is because the memory-load reduction we are considering – aside from the presence of constituents – depends on corresponding rules of semantic composition, which presuppose a representational means. Although humans in this juncture may have surpassed the few-dozen-word threshold, if they hadn't "discovered" representational mechanisms, they would be stuck with a system which, communication-wise, is actually *less* efficient than it would have been prior to the vocabulary explosion. There might then have been evolutionary pressure to "discover" representations, but it is unclear how that would have come about. More likely, our ancestors would use what they had, existing in whatever conditions they had experienced for eons, now partly challenged by unnecessary phonetic codings.

Moreover, assuming vocabulary drift given the sociology of ancestral human clans (if modern clans are any indication), it is only natural that linguistic differences started emerging and actively being pursued as signs of identity, thus transmitted culturally (cultural transmission has recently been discovered in all other apes, including relatively distantly related orangutans, as largely reported also in the popular press). They would be of the same sort that one finds in songbirds, thus implying learning of clan or tribe-specific vocabulary items and combinations. The latter assumes that given linear orders may be perceived and somehow significant. That is, for different groups the thought that, say, “I hit you” might be expressed in (six) different ways (excluding, in this thought experiment, constituent structure or a putative internal/external argument distinction):

(19) a. I you hit. b. I hit you. c. You hit I.
d. You I hit. e. Hit you I. f. Hit I you.

Each of these “dialectal” orders would be entirely arbitrary, but assuming frozen proto-grammatical relations, expressed in sequence, it is a reasonable way of cutting on otherwise massive ambiguity (which grows factorially with more symbols). That is to say, the system of “knowledge” (if it can be so called) would really not code or even identify the different orders in (19). However, *use* strategies would arguably force speakers to locally select one among the logically possible orderings, and stick to it within the community for the sake of consistency. Presumably an arbitrary decision, if carried through by a dominant individual, may trickle down the hierarchical structure of a clan, perhaps become a signature of the group. It should be remembered that these are the ideas often found in the functionalist literature. They may have been right, not so much for language as for proto-language, which is much less structured. At this point we have some form of proto-variation, perhaps a factor in the early diaspora if clans cherish their own dialects (thus favored by evolution for the same sort of reasons that Lorenz (1963) finds for aggression in fish of the same kind: they spread the gene pool).

14.5.4 Morphology as Frozen Syntax

But the very small clan/tribe populations implied in this scenario must have interbred, short of falling into genetic traps created by isolation. Again, if modern tribal societies are any indication, the gene exchange must have brought with it, with a significant probability, a new element: multilingualism. Quite plainly, several proto-languages are implied in the present scenario, coupled with the need for different societies to interbreed. Thus some new families or clans formed in these dynamics must have involved at least two co-existing proto-languages. In fact, perhaps *many* such units existed. Computational simulations in progress by Osherson and Weinstein indicate that bilingualism has adaptive consequences, under the reasonable assumption that bilinguals have access to more mates. (Obvious though this may seem, computational simulations of this sort often reveal surprising, unintuitive results, and thus it is good to have reliable evidence of the right sort.) If so this state of affairs may have thrived, and it would not be long before a new situation would emerge for populations with linguistic diversity: their offspring may be receiving conflicting data. If input dialects are sufficiently different both in vocabulary and in basic syntax, this might not be a problem: evidence from one would not interfere with evidence for the other, as they are just too distinct. A more intriguing possibility emerges when the dialects are similar enough in basic phonotactics and vocabulary, albeit sharing different (arbitrary) sequencings to express proto-grammatical relations.

Thus imagine the daughter of a woman who says *I hit you* living in a community (perhaps with siblings who share her dialect) for whom that thought is expressed as in any of the other orders in (19). This learner may have a harder time than a child in a mono-lingual environment in figuring out the value of the various signals, or the particular order of the grammatical sequences in either her mother's or her father's dialect. Suppose for instance that the father says *Jane she hit* in the same contexts where the mother would say *I hit Jane*, for example one where the child has misbehaved, say hitting a sibling, and both parents are angry. Suppose this child has already learned from her mother the import of *hit* and of *Jane* as a name for herself, and a basic <subject, verb> order. Then she hears the father say *Jane she hit*, perhaps very saliently, screamed at her. What is she supposed to do with the token *she* uttered by the father? Statistical regularities, in an interesting scenario with roughly equal weight for each grammatical possibility in the learning context, won't solve this puzzle. Then again, the sentence can be parsed if the extra element is somehow ignored, as *Jane hit* - an accurate statement in the present circumstance, as Jane did hit her sibling. Any other interpretation, assuming the child's lexical knowledge and the basic rule acquired from the mother, makes little sense: Is *she* some kind of action performed over hittings? The question, of course, is how *she* can be "ignored". But here we have an answer if we take the element to be a computational virus, and we let the grammatical system loose to eliminate it, in the manner described above.

If this scenario is stable enough in one of the many clans spread throughout Central Africa at the time, in effect the birth of morphology would have taken place.[7] Within the same generation of children introducing this noise in their parent's rudimentary system, a magnificent cultural innovation would have ensued, much as pearls arise from intruding grains of sand. Once transformations tackle morphological intruders, the system would catapult itself towards a new dimension. It would presumably memorize its immune dynamics, it would be capable of discovering that it carries symbolic properties internal to it, it would free up new computational spaces capable of expressing no less than quantification. Furthermore, the more complex system thus emerging would only amplify the dynamics just described, with more room for serious mismatches in bilingual scenarios, particularly once the possibility of meaningful recursion is recognized in the process. Hence a kind of "auto-catalysis" would ensue, with more morphology arising in the process, and thus more transformations to eliminate it, and so on. If so, the cultural innovation would gain momentum – it would be highly adaptive. The potential risk of losing proto-language due to the excessive "opportunities" provided by FOXP2 would become the gain of actual language, a potential crisis turned into an extraordinary gain.

[7] We credit Talmy Givon (1973) for his intuition that 'Today's morphology is Yesterday's syntax.'

14.5.5 Children are to Blame

In the present scenario, linguistic variation is essential, as it predates –and establishes– FLN in its full potential. Without variation, there would have been no proto-morphology, thus no need to eliminate it through transformations, nor all the advantages they confer as a consequence. FOXP2 plays a significant role in that variation if a mutation in this gene ultimately allowed it, within the confines of a system which was not really prepared to absorb the phonetic flexibility that, it seems, comes from that particular mutation. It is possible that after the initial, accidental birth of morphology (not unlike the accidental viral infections that may have been behind the emergence of pseudo-knots in nucleic acids, for instance), the resulting “pseudoknots” shown in the Figures could have lead to other mutations in some other part of the genome which could, in turn, assume the viral effect of morphology as good for the linguistic system as we know it, now in biological – not just cultural – terms. At that point the need for morphology would be hard-wired, and UG in its present form would be entirely in place.

We claimed in section **14.4.3** that our virus idea could be seen as an implementation of the suggestion made by Hauser *et al*. (2002) that FLN could have originated as a change of recursion from domain-specific to domain-general. Although it is possible that each of these ideas is independent (thus either could be wrong without affecting the veracity of the other), it is not hard to connect the two. There are two central aspects to our account: (i) the virus logic and (ii) a story about how the virus got into the system. The virus logic provides a good modeling for any dimensional change from a structure with the complexity of a phrase (level two in the Chomsky hierarchy) to a structure with the complexity of a transformation (level three in the Chomsky hierarchy). The more speculative story about the virus origin is of course specific to language, and therein lies the key to substantiate the Hauser, Chomsky & Fitch line. With them we believe that proto-language need not have been, and probably was not, symbolic, thus may not have been a bona-fide communication system even if it had communicative consequences. Whatever it was, the system did have, however, implicit or explicit recursive capabilities (probably the former if it was solipsistic to a serious extent). However, the moment that system is forced by the viral logic out of its confines and into context-sensitivity territory, it must a fortiori be symbolic. At that point the extension falls of its own weight: if the system has internal symbolic properties it is only natural that it would, then, be used for symbolic purposes.

All of these ideas are consistent with current understanding in a variety of disciplines (including generative linguistics, a rare circumstance), and are furthermore testable through computational modeling and, hopefully, population and individual genetics. In the picture just presented, the evolution of FLN is tightly connected to language acquisition, thus is to be “blamed” on mistakes children make. At least from the point of view of adult language. This is very reminiscent in spirit of the logic behind Lightfoot's (1999) treatment of language change as driven by learnability considerations (see also Yang, 2003 for related ideas). Of course, the difference is that in the language-change instance UG has already evolved – and thus we are only speaking then of variation taking place within the open program this system implies – whereas in the evolution scenario the task is to evolve UG to start with, in particular its computational characteristics associated to transformations. But the philosophy behind is identical in each instance: children are both elegant and revolutionary forces behind linguistic structuring. In Lightfoot's scenario, this is because children haven't fixed the details of the adult system, and therefore they go with whatever analysis of primary linguistic data fills in the open specifications of UG most economically (the elegant part). If that means changing the dominant paradigm in the adult community, well, so much the worse for the dominant paradigm. Herein the revolutionary bit. In the evolutionary scenario, the elegant analysis arises, at least in the virus story as told above, in terms of responding to a problem that conflicting data produce in a bilingual situation: transformations may have been only dormant in a system that had evolved to the level of FLB, much as in a sense they are, at least in scientific representations, in nucleic acids themselves; but when they got summoned to serve an active role in eliminating viral morphology, not only did they get rid of the intruder, but furthermore they resulted in a brilliant array of secondary structural consequences of the (assumed) symbolic sort. That's elegance with a vengeance, which is where the revolutionary bit comes in. It is at this point that a component of a modular system arguably got co-opted for external uses, with massive consequences.

But just as there is much room for the miraculous (in the sense that life and intelligence seem to us miraculous), there is also a considerable amount of room for the ordinary, even crucially so. Lightfoot's story about language change would not have been plausible if input data of the primary linguistic sort hadn't experienced any drift. That is, if the input data of generation X is identical to the input data of a parent generation of baby boomers, given equal input there ought to be equal output, assuming (as we do) that the black box in between is more or less identical. But of course, the input data is pretty messy, for the same reason that societies, in a sense, are messy too. This constitutes the other major line of reasoning about linguistic change within generative grammar, advocated by Kroch (e.g. Kroch, 2001): there is sociology to language, which means languages get also reshaped in the hands of adults, perhaps less catastrophically than they do in the world of children. No slow linguistic drift would equate to no differences in input data and thus no catastrophic core changes. Which is to say that a Kroch-style mode of explanation is an essential complement of a Lightfoot-style account of fundamental language changes. In the evolutionary scenario, too, we need these complex dynamics: without the messy emergence of morphology, itself possibly a consequence of immunization of extraneous syntax in bilingual situations, there wouldn't have been the need to liberate the mighty transformations. It recalls virtually any other major emergence of form in the universe as we know it. To start with, without a messy moon which emerged from asteroid crashes against Earth, there wouldn't have been tides, and hence, presumably, terrestrial life on the planet. The thought is both humbling and essential to the understanding of complex dynamic systems: take a messy pebble from a smooth current and the pretty eddies go away. Elegant form often responds to ugly challenges, which is when the system starts cooking - as they say, “at the edge of chaos”.

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