

# TREE MAXIMIZATION AND THE GENERALIZED EXTENDED PROJECTION PRINCIPLE\*

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In this paper we argue that a number of unexplained and stipulative properties of the grammar (such as the Generalized Extended Projection Principle, Binary Branching, Labeling) find a functional explanation, if we view them as correlates of a general desire for the grammar to maximize trees in such a way that they result in a Fibonacci-like sequence of maximal categories.

## 0. Introduction

Since Chomsky's (1981) addition of the requirement that every sentence have a subject to the Projection Principle, the apparent stipulative nature of this constraint has been a source of worry for generative grammarians. The empirical basis of the Extended Projection Principle (EPP) is well-established but the external motivations for why Universal Grammar should contain such a requirement are fairly mysterious. This lack of explanation has been compounded in more recent versions of the Minimalist Program, where the EPP has been generalized to all types of specifier positions (e.g., Chomsky 2001).

At the same time, important work in the philosophical foundations of Minimalism has suggested that universal syntactic principles, in particular those governing the simple, mathematical computational system, should follow from general physical principles that govern the way biological systems emerge in the phenotype. For example, Uriagereka (1997) has claimed that linguistic structures exhibit the mathematical properties of the "Golden Mean" as exhibited, for example, in the Fibonacci Sequence (0, 1, 1, 2, 3, 5, 8, 13, etc). In this speculative squib, we observe that one particular Fibonacci-like sequence in tree structures which are maximized in terms of specifiers and complements might explain why languages aim towards filled specifiers as stipulated by the generalized EPP. This, in turn, we claim makes some interesting predictions about the binarity of the MERGE operation, the ambiguity of terminal complements and the nature of the labeling operation subsumed in MERGE.

## 1. A Minor Mathematical Observation.

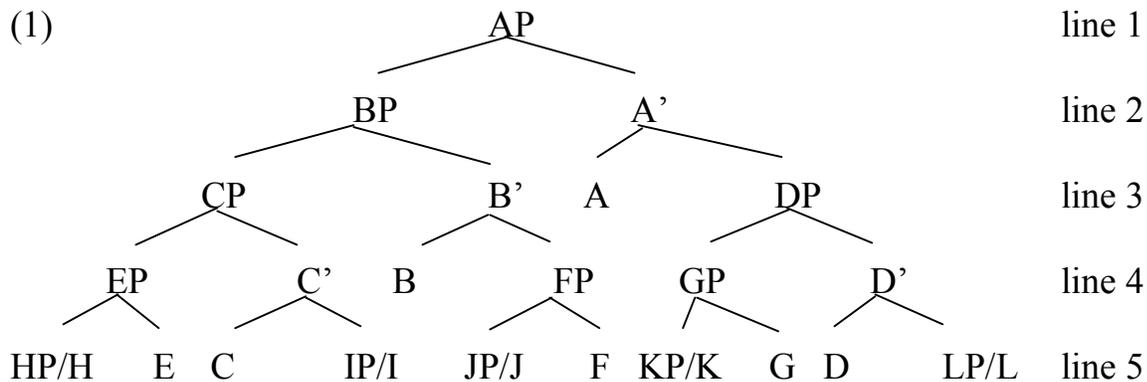
Consider a tree, generated by MERGE from the numeration  $\{A, B, C, D, E, F, G, H, I, J, K, L\}$  where every specifier and every complement position has been filled<sup>1</sup>,

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<sup>1</sup> At the bottom-most layer of such a tree, some nodes may be ambiguous between specifier and complement status. For example, HP/H in (1) is simultaneously a specifier and a complement, in

and each item has been merged only once. Further, let's annotate this tree with the maximal categories as defined by Chomsky (1994)—where a label that is immediately dominated by the projection of another category is an XP<sup>2</sup>—and for ease of exposition we annotate other non-terminal nodes as X'. One possible version of such a tree is given in (1). Nodes that are ambiguous between terminal and maximal categories are annotated XP/X.



If we count the number of XPs in each line of this derivation, counting XP/X<sup>o</sup> ambiguous cases as XPs, we see a partial Fibonacci sequence (1, 1, 2, 3, 5). This property is true of all trees that are maximized in this way. The first (top) level -- the root node -- consists of one XP node. The next level contains one XP (the specifier of the root) and one X'. Thereafter, in the *n*th level there is one XP for each YP in the (*n*-1)th level (the specifier of that YP), and one XP for each YP in level *n*-2 (complement of that YP); no other XPs occur in the *n*th level. Letting the function XP(*n*) represent the number of XPs in the *n*th level, we see that XP(1) = 1, XP(2) = 1, and for *n* > 2, XP(*n*) = XP(*n*-1) + XP(*n*-2). Then XP(*n*) = Fib(*n*), the Fibonacci function which yields the familiar sequence 1<sup>3</sup>, 1, 2, 3, 5, 8...

Needless to say, real syntactic structures are not maximized in the way (1) is. However, in the ideal case it is clear that 'maximizing' the tree entails filling all specifiers. Thus the tendency encoded in the generalized EPP can be derived from this pattern. The fact that real sentences don't fully maximize in this manner can be seen to be due to the externally imposed limitations of creating a meaningful sentence. As such the EPP can be viewed as a means towards maximizing the tree towards "Fibonacci-hood", but other factors interfere to limit the degree to which this is achieved. In the world of biology, similar effects can be seen that interrupt idealized Fibonacci qualities. For example, the fractal quality of zebra stripes can be interrupted by the appearance of an ear, or a scar. Likewise, the number of

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the traditional sense of X-bar theory (cf. Chomsky 1995's slightly different definitions); further branching below this level would disambiguate these structures.

<sup>2</sup> See also the principles of determining maximal and minimal status discussed in Speas (1992)

<sup>3</sup> The Fibonacci sequence is often claimed to "start with" a 0, we assume that for reasons of conceptual necessity, there is no "level 0" in a sentence that has some set of nodes, thus the number 0 is absent from the sequence based on a syntactic tree. In principle a Fibonacci sequence can start anywhere in the set of whole numbers.

petals in a flower may not fall exactly into the Fibonacci sequence; it is a tendency, not an absolute law. With this in mind, the fact that the sentences of human languages aren't fully fractal isn't surprising.

## 2. Some Further Consequences.

In addition to predicting that specifiers should be filled, a necessary consequence of tree maximization is that XP complements should also apparently be obligatory. This effect may appear to be partly counterintuitive; for example, we are left with the problem that every head must have an XP complement, but this would mean that we would never have a line in the tree with only terminals. This is clearly a problem since, at least on the face of things, the final line should consist of nothing but terminals.

Nevertheless, we believe that this pressure for the tree to be as Fibonacci-like as possible -- via maximization -- may provide an explanation for a few of the more stipulative properties of the operation MERGE. Let us distinguish three parts of the operation:

- (2) a) Take two (and only two) terms
- b) Combine them in a set
- c) Give the set a label.

Of these three parts, only (2b) has a clear motivation (presumably compositionality). Parts (2a) and (2c) appear to be stipulations (However, see Kayne (1984) for a discussion of the motivations of binary branching). We believe that both these properties fall out directly from the functional pressure of tree maximization.

Let us start first with the binarity stipulation in (2a). If MERGE were allowed to optionally select three terms and merge them into a ternary structure, then the fractal Fibonacci sequence of maximal categories would disappear. For example, in line 3 of (1) above, if A were to be merged with both DP and another maximal category (say YP) then the sequence would be 1, 1, 3, ... Due to the optionality of two vs. three term merging, it would be impossible to predict where such breaks in the sequence would occur. Similarly, if MERGE was allowed to apply to singletons, then we would predict non-branching structures of the form in (3):

- (3)           XP  
              |  
              X

Chomsky (1994) argues that such structures should be disallowed (see also Carnie 2001, and cf. Kayne 1994). Interestingly, the conflicting pressures of saying a string of linguistic atoms (words), and the pressure of having a Fibonacci-like sequence of maximal categories results in structures like that in line 5 of (1), where

we have elements that are ambiguously XPs and X°s (see Speas 1992 and Carnie 1995, 2001 for empirical arguments that ambiguous structures like these are motivated). It appears, then, that the functional pressure to achieve a fractal structure by tree maximization might explain why non-branching and ternary-plus branching would be disallowed from the MERGE operation.

The fact that constituent structures have labels also appears to be a stipulation. Indeed Collins (2002) claims that this part of the MERGE operation should be abandoned. A discussion of his arguments would take us too far afield. However, we note that, in fact, labels provide the necessary mechanism for determining whether a node is an XP or not (if a node is immediately dominated by a node bearing a different label, then it is an XP). As such if grammar is aiming towards a structure where a Fibonacci sequence of XPs is required, then a mechanism for determining “XP” hood is necessary (contra both Collins 2002 and Carnie 2001). Tree maximization thus provides an external motivation for this part of the MERGE operation as well.

### **3. Speculations and Worries.**

In this short paper, we have attempted to offer some speculations about why such constraints and operations as the EPP, labeling, and binary branching might exist in a linguistic system. We have claimed that these things might follow if, as Uriagereka has claimed, the physical properties of the universe push biological systems into particular mathematical patterns. Syntactic structure, like the stripes of zebras and the petals on a flower, strives towards the particular mathematical symmetry found in the Fibonacci sequence. Of course, we have no way of proving these claims. We merely note that the structural requirements needed to produce the Fibonacci sequence (in the ideal case) are precisely some of the most surprising properties of the computational system.

There are, of course, many possible objections to the characterization we have given. One that strikes us as particularly important is the claim that the EPP is not universal. McCloskey (1996) for example, has claimed that some VSO languages appear to lack EPP effects (there is no obligatory movement to subject position, there are no expletives, etc.). If McCloskey’s assertions prove to be correct, then obviously our speculations rest on far less stable ground. However, if alternative explanations for McCloskey’s facts prove tenable, then perhaps our observations offer some insight into the nature of syntactic structure.

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