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The Mirror Alignment Principle

Morpheme ordering at the morphosyntax-phonology interface

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Abstract
As codified by Baker's (1985) "Mirror Principle" (MP), the linear order of morphemes within a word generally correlates with hierarchical syntactic structure. While Baker uses morphological ordering to demonstrate the inseparability of syntax and morphology, he simply assumes cyclic morphological concatenation as the formal means by which MP-compliance is enacted in the grammar.

This paper develops a new framework for morpheme ordering, the *Mirror Alignment Principle* (MAP), which derives the MP while avoiding some of the shortcomings of cyclic morphological concatenation. The MAP is a morphology-phonology interface algorithm that takes morphosyntactic c-command relations and dynamically generates a ranking of alignment constraints (McCarthy and Prince 1993) in the phonological component. All possible morpheme orders are considered and evaluated by an Optimality Theoretic (Prince and Smolensky [1993] 2004) phonological grammar, which selects the optimal surface order through constraint interaction. Even though morpheme order is computed in the phonology, the driving force behind this order is the syntax/morphology. This link between grammatical components generates MP-compliant morpheme orders.

This paper focuses on two case studies. First, it will show how the MAP is consistent with the complex interaction between MP-satisfaction and the "CARP template" in Bantu (Hyman 2003). Second, it will show that the MAP can explain intricate ordering alternations within Arabic's root-and-pattern verbal system. This will demonstrate that MP-behavior can indeed be identified even in nonconcatenative morphological systems.

Keywords Mirror Principle · Alignment · Morpheme ordering · Bantu CARP template · Arabic nonconcatenative morphology · Infixation · Phonology-morphology interface

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1 Introduction

1.1 Background

Even before Baker's (1985) influential proposal of the "Mirror Principle" (MP), it was widely recognized that the linear order of morphemes within a morphologically complex word generally correlates with hierarchical syntactic structure (see also, e.g., Abasheikh 1978; Muysken 1979, 1981, 1986; Baker 1988a). In morphologically complex words, the exponents of morphosyntactic terminals that are *lower* in the syntactic structure (or, in Baker's terms, apply earlier in the syntactic derivation) generally surface *closer* to the root than the exponents of higher morphosyntactic terminals. In broad terms:

(1) The Mirror Principle (Baker 1985:375)
Morphological derivations must directly reflect syntactic derivations (and vice versa).

While Baker uses morphological ordering as a means of demonstrating the inseparability of syntax and morphology, he does not in detail explore the formal means by which MP-compliance is enacted in the grammar.

Baker assumes that the MP follows from cyclic morphological concatenation, which joins (the exponents of) morphosyntactic terminals that are adjacent (i.e. sisters) in the syntactic structure (Baker 1985:377–378). Embick (2007) formalizes this sort of concatenation operation by proposing a framework inspired by Kayne's (1994) Linear Correspondence Axiom for syntactic linearization (see also Julien 2002). However, as recognized in Embick (2015), while this approach may be able to limit the set of possible morpheme orders to those which obey the MP, it underdetermines the choice between multiple possible MP-obeying orders. Some language-specific property (or set of properties) must be brought to bear in order to resolve this indeterminacy. Furthermore, identifying morphological concatenation as the formal mechanism behind morpheme ordering excludes nonconcatenative morphological processes—especially things like Semitic "root-and-pattern" morphology—from the phenomena which can be directly assessed through the lens of the Mirror Principle (Baker 1985:400–403; LeTourneau 1997).

1.2 Proposal and architecture

This paper develops a new framework for morpheme ordering that derives the Mirror Principle while avoiding some of the shortcomings of a morphological concatenation-based system. The core of the proposal is an algorithm that applies at the morphology-phonology interface, called the *Mirror Alignment Principle* (MAP). The MAP takes the hierarchical structure of morphosyntactic terminals generated by the syntax (and operated on by the morphology) and translates it into a ranking of alignment constraints (McCarthy and Prince 1993; Prince and Smolensky [1993] 2004) that is legible by the phonological component. The phonology considers all possible morpheme orders (and phonological modifications thereof), and selects the surface order that is optimal according to the constraint ranking, which consists of both alignment constraints and more typical phonological constraints.

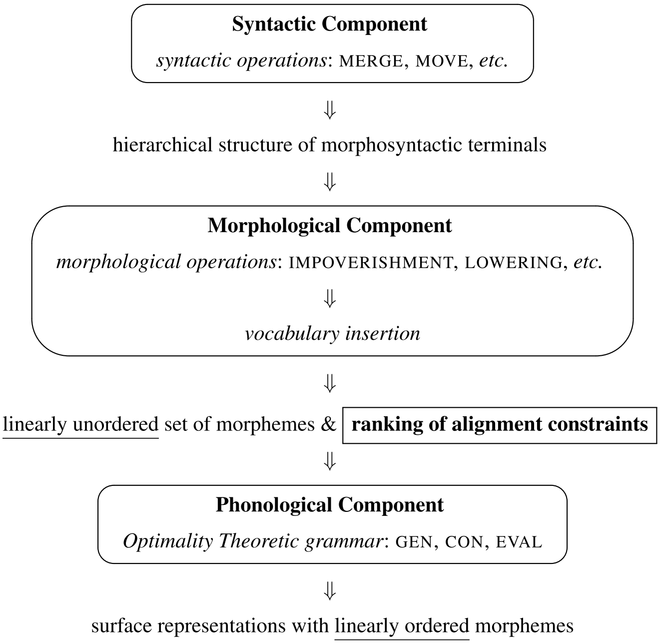


Fig. 1 The modular architecture of the PF branch

This proposal assumes a modular, feed-forward grammatical architecture with the characteristics schematized in Fig. 1 (cf. Embick 2015). Note that Fig. 1 shows only the "PF" (phonetic/phonological form) branch of the grammatical derivation. Following Chomsky's (1986) "Y-model," I assume that semantic operations and interpretation ("LF"; logical form) take place on a separate track from externalization. The MAP is thus a purely PF-based theory of ordering.

The syntax generates a hierarchical structure of morphosyntactic terminals (following basically Chomsky's 1995, *et seq.* Minimalist Program). This hierarchical structure serves as input to a discrete morphological component (as in Distributed Morphology (DM); Halle and Marantz 1993) which has the ability to perform its own operations on hierarchical structure (see, e.g., Embick and Noyer 2001; Arregi and Nevins 2012; Harizanov and Gribanova 2019). Vocabulary Insertion then endows the morphosyntactic terminals with phonological content.

These vocabulary entries serve as the input to an Optimality Theoretic (OT; Prince and Smolensky [1993] 2004) phonological grammar. The OT grammar consists of three components: GEN, CON, and EVAL. The generative component (GEN) furnishes all possible output candidates which can be related to the material in the phonological input; for the present purposes, the output candidates include all conceivable orderings of the morphemic exponents in the input. Each language has a unique constraint ranking (CON), i.e., an ordered list of phonological constraints (minimally including markedness constraints, faithfulness constraints, and alignment constraints). The evaluative component (EVAL) applies constraint violations to the various output candidates, and selects the candidate with the optimal (i.e. least worst) ordered set of constraint violations.

The part of this grammatical architecture which is responsible for determining the linear order of morphemes is the *ranking of alignment constraints* produced by the morphological component. This ranking is determined by the Mirror Alignment Principle (defined below), which converts c-command relations into ranking relations. Even though morpheme order in this system is computed in the phonology, the driving force behind this order is the syntax/morphology. This link between grammatical components generates MP-compliant surface morpheme orders.

Note that Fig. 1 presents Vocabulary Insertion within the morphological component. However, the current proposal crucially assumes that linear order between morphemes is absent until the phonological component. Therefore, any aspects of Vocabulary Insertion which are truly dependent on cross-morpheme linear information must be derived in the phonology. Full exploration of the relationship between Vocabulary Insertion and the MAP approach will be taken up in future work.

1.3 Outline

This paper is structured as follows. Section 2 lays out the formal details of the proposal. It defines and exemplifies the Mirror Alignment Principle, and shows how the use of alignment constraints can restrictively generate morpheme order when dynamically connected to the syntax. Sections 3–5 explore two case studies of classical morpheme ordering problems: the first showing that the MAP approach is *sufficient* to capture a complicated concatenative morphological system; the second demonstrating that the MAP approach is *necessary* to capture the intricacies of a recalcitrant nonconcatenative morphological system.

Section 3 explores Mirror Principle effects, and Mirror Principle violations, in the Bantu languages, focusing on Chichewa (Mchombo 2004). Mirror-image orderings of Causative and Reciprocal in Chichewa directly follow from the formulation of the MAP. However, these sorts of mirror-image orderings are embedded within a more complicated system, termed by Hyman (2003) the "CARP template." In this system, some morpheme pairs have "asymmetrically compositional" (Hyman 2003) ordering properties, and other pairs have fixed orders regardless of semantic scope (Ryan 2010). Both types, either in part or in whole, violate the MP. Nonetheless, the MP must remain in force in order to generate certain aspects of asymmetric compositionality. I will show that the MAP successfully captures the distribution of order-interpretation pairs in the basic cases of both asymmetric compositionality and fixed order, and is consistent with various approaches to the CARP template (and templatic morphology generally), situated at different time-points in the grammatical derivation. I further show that supplementing the analysis with Base-Derivative faithfulness constraints (Benua 1997) allows for a straightforward explanation of certain cases of suffix doubling.

Sections 4 and 5 show how the MAP framework can make headway on a long-standing problem in theoretical linguistics: Semitic nonconcatenative morphology, as instantiated in Arabic. In Sect. 4, I focus on two puzzles in Arabic regarding the relative order of the root and certain affixes, one involving the Reflexive morpheme

/t/ and one involving the two basic types of Causative formations. The exponents of Reflexive and Causative appear as prefixes in some morphosyntactic categories but as infixes in others. In previous frameworks based on concatenation and/or prosodic templates (cf. McCarthy 1979, 1981), these and other ordering alternations had to be stipulated or denied entirely. Yet, in the MAP framework, these alternations find a unified explanation in terms of statable syntactic differences, in the form of a novel empirical generalization linking syntactic structure with linear order: these morphemes appear as infixes when they are the first head to combine with the root, but they appear as prefixes when they attach higher.

Section 5 integrates this morphosyntactic analysis with a full-fledged phonological analysis of the language's broader root-and-pattern system. I show that combining the MAP-based alignment constraints with phonotactic constraints on consonant sequences and faithfulness constraints against segmental splitting restrictively accounts for the detailed segmental ordering patterns across the canonical, productive verbal formations in the language. This analysis shows both that we need a theory of linearization that allows for fine-grained interaction between purely phonological considerations and morphological ordering preferences, and that the MP is indeed relevant broadly in nonconcatenative morphological systems.

Section 6 concludes with a summary of the main contributions of the paper and a discussion of how the general proposal could be extended to account for ordering of constituents above the word level.

2 The Mirror Alignment Principle

In developing the theory of Generalized Alignment, McCarthy and Prince (1993) argue for the existence of alignment constraints, a species of constraint which demands that specified edges of phonological and/or morphological constituents coincide in the output representation. As recognized in McCarthy and Prince's original proposal, and implemented in various ways thereafter (cf. Anderson 1996; Potter 1996; Hargus and Tuttle 1997; Trommer 2001; Yu 2007; *a.o.*), one possible application of the theory of Generalized Alignment is in the determination of morpheme order. While a number of subsequent critical works (e.g. McCarthy 2003; Yu 2007; Paster 2009; Ryan 2010) have argued that an unconstrained use of (gradient) alignment constraints makes various undesirable predictions, some of these ills are alleviated by the present proposal, which expressly limits and contextualizes the use of alignment constraints.

The proposal outlined in this section takes Generalized Alignment as its starting point, but significantly constrains its power by placing principled restrictions on how alignment constraints operate in the phonology. Namely, the relative ranking of alignment constraints is not free, contrary to the normal conception of free ranking of constraints in OT. Instead, their ranking, although variable across derivations, is deterministically fixed for each given derivation, transmitted from the morphological component by means of the Mirror Alignment Principle (MAP). This section defines the MAP, and illustrates how it constrains the operation of Generalized Alignment in a way that derives the Mirror Principle (Baker 1985).

2.1 Generalized Alignment

McCarthy and Prince (1993) define Generalized Alignment as follows (cf. Hyde 2012):

(2) Generalized Alignment [GA]
Align (Cat[egory]1, Edge1, Cat[egory]2, Edge2) $=_{\text{def}}$
$\forall$ Cat1 $\exists$ Cat2 such that Edge1 of Cat1 and Edge2 of Cat2 coincide.
Where
Cat1, Cat2 $\in$ P[rosodic]Cat $\cup$ G[rammatical]Cat
Edge1, Edge2 $\in$ Right, Left
...A GA requirement demands that a designated edge of each prosodic or morphological constituent of type Cat1 coincide with a designated edge of some other prosodic or morphological constituent Cat2. (McCarthy and Prince 1993:80)

Alignment constraints that align morphological categories to prosodic categories are constraints on the morphology-phonology interface. Since morpheme ordering is about determining the linear relationship between morphemes in the phonological representation, these constraints can enforce morpheme order. In this paper, I focus specifically on alignment constraints that relate morphological categories to an edge of the prosodic word (much as in Trommer 2001). All claims about alignment are thus restricted to the activity of this type of alignment constraint. Further research is needed to determine whether other types of alignment constraints are also necessary, and whether there are principled restrictions on their operation in the grammar.

When a single alignment constraint is active in a phonological derivation, it will appear as though its effect is simply to place the edge of the relevant morphological category at the edge of a particular prosodic category (or as near to it as possible, subject to higher-ranking phonological considerations). However, a different picture of alignment constraints emerges when we examine how they can interact with one another. Consider the following schematic example.

Suppose that there is a word that contains a Root plus three affixes: X, Y, and Z. By hypothesis, the underlying phonological representation for this word is a *linearly unordered* set of the four morphemes /Root, X, Y, Z/ (cf. McCarthy and Prince 1993; see also Wolf 2008:80). The hypothesized absence of underlying order is limited to linear order; the syntax, semantics, and morphology all still operate over ordered, hierarchical structures. (Though do note that this presupposes that morphology does not contain linear information, beyond precedence relations within individual phonological exponents.) Each morpheme (including Root; see immediately below) is referenced by an alignment constraint. As mentioned above, I assume that each morpheme is referenced by a single, word-edge-oriented alignment constraint. In this example, all three constraints are defined with reference to the *right* edge of the (prosodic) word, as shown in (3):

(3) Alignment constraints for the input /Root, X, Y, Z/

a. **ALIGN(X, R; PWD, R)** [ALIGN-X-R]
Assign one violation for each segment intervening between the right edge of morpheme X and the right edge of the prosodic word.

b. **ALIGN(Y, R; PWD, R)** [ALIGN-Y-R]
Assign one violation for each segment intervening between the right edge of morpheme Y and the right edge of the prosodic word.

c. **ALIGN(Z, R; PWD, R)** [ALIGN-Z-R]
Assign one violation for each segment intervening between the right edge of morpheme Z and the right edge of the prosodic word.

Each alignment constraint is maximally satisfied when the morpheme it references is absolute rightmost within the word. However, in any candidate output, only one morpheme can successfully attain this position and thus achieve perfect satisfaction of its alignment constraint, assuming no coalescence or deletion. This means that satisfaction of one of these alignment constraints entails increased violation of the others. These constraints, therefore, will be in *direct competition* for a particular position in the output (here, word-final position).

The following example shows the violation profiles for each possible combination of the three morphemes X, Y, and Z. I consider here only candidates where each of these morphemes follows the Root. This will be the result if the Root has a left-alignment constraint, the reverse orientation of the affixes' alignment constraints, regardless of its relative ranking. Additional orders will be considered below, but assume for now that ALIGN-ROOT-L is operative and rules out these additional orders. For convenience, violations are assigned here by treating each morpheme as if it were a single segment.

(4) Violation profiles

/Root, X, Y, Z/		ALIGN-X-R	ALIGN-Y-R	ALIGN-Z-R
a.	Root-X-Y-Z	**	*	
b.	Root-Y-X-Z	*	**	
c.	Root-X-Z-Y	**		*
d.	Root-Z-X-Y	*		**
e.	Root-Y-Z-X		**	*
f.	Root-Z-Y-X		*	**

Each candidate order has a total of three alignment violations (the morpheme second from the right incurs one alignment violation; the morpheme third from the right incurs two), but distributed across the different constraints. The six possible ranking permutations of the three alignment constraints each correspond to the selection of one of the six candidate orders.

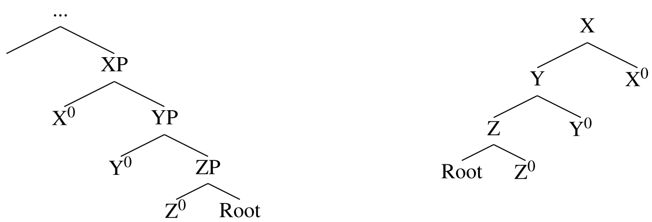
2.2 The Mirror Alignment Principle algorithm

Optimality Theory generally assumes that, in the absence of evidence to the contrary, any set of constraints is freely rankable. Under such an assumption, we would expect that all of these rankings would be permissible, and we would have no prior expectation as to which of the six candidate orders the language should display. In other words, for the set of languages that allow morphemes X, Y, and Z to co-occur, the factorial typology predicts languages of all six sorts.

However, it has long been recognized that the order in which morphemes appear in a word generally reflects the relative positions that their corresponding morphosyntactic terminals occupy in the hierarchical morphosyntactic structure (Abasheikh 1978; Muysken 1979, 1981, 1986; Baker 1985, 1988a *et seq.*; cf. Rice 2000; Stiebels 2003; *a.o.* on a semantic interpretation). Specifically, the exponent of a terminal that appears higher in the syntactic structure will be *more external* in the word (i.e. further from the Root) than the exponent of a lower terminal. Baker (1985) termed this generalization the "Mirror Principle" (MP). Given this, we *do* have prior expectations about the relative order of morphemes in complex words.

Taking our schematic example, let's assume that we have independent syntactic evidence that the morphemes X, Y, and Z stand in the hierarchical syntactic relation shown in (5):

(5) Syntax of /Root, X, Y, Z/
 a. Base-generated structure → b. Complex head



For this structure, the MP dictates that Z surfaces closest to the Root, Y surfaces next closest, and X surfaces farthest away. This is candidate order (4f) [Root-Z-Y-X]. The ranking of the three alignment constraints in (3) which generates candidate order (4f) is the one in (6) below (continuing to assume that the Root is leftmost, dictated by Align-Root-L).

(6) Generating the Mirror Principle order
 i. *Ranking*: Align-X-R ≫ Align-Y-R ≫ Align-Z-R
 ii. *Tableau*:

/Root, X, Y, Z/		Align-X-R	Align-Y-R	Align-Z-R
a.	Root-X-Y-Z	*!*	*	
b.	Root-Y-X-Z	*!	**	
c.	Root-X-Z-Y	*!*		*
d.	Root-Z-X-Y	*!		**
e.	Root-Y-Z-X		**!	*
f. ☞	Root-Z-Y-X		*	**

What is important here is the relationship between the hierarchical structure in (5) and the ranking in (6). The highest terminal in the syntactic tree is X; the highest-ranked constraint in the constraint ranking is Align-X. The next highest terminal in the syntactic tree is Y; the next highest-ranked constraint is Align-Y. The lowest terminal in the syntactic tree is Z; the lowest-ranked constraint is Align-Z. This illustrates how mapping hierarchical syntactic relations onto ranking relations among alignment constraints generates a MP-compliant order of morphemes. If we characterize hierarchical relations using (a slightly modified version of) c-command (see immediately below), this mapping can be defined as in (7):

(7) **The Mirror Alignment Principle (MAP)**

a. If a terminal node α *asymmetrically c-commands* a terminal node β, then the alignment constraint referencing α *dominates* the alignment constraint referencing β.

b. *Shorthand*: If α c-commands β → ALIGN-α ≫ ALIGN-β

Looking at the MAP, there are two different ways in which a surface structure can comply with the MP. When ALIGN-α and ALIGN-β reference the same edge, applying the MAP-determined ranking will result in α being closer to the desired edge than β, i.e., the competition will be resolved in favor of α. From the reverse perspective, this results in β being closer to the Root than α is; this is the canonical characterization of MP-compliance. If, on the other hand, the alignment constraints reference opposite edges, then both alignment conditions can be satisfied simultaneously. Such would be the case when, descriptively speaking, one morpheme is a prefix and the other is a suffix, e.g. ALIGN-α-LEFT but ALIGN-β-RIGHT. Since the two conditions do not interact, MP-satisfaction is essentially vacuous.

The tableau in (6) demonstrates why alignment constraints must be defined gradiently, rather than categorically (*contra* McCarthy 2003). If they were defined categorically—something like "Assign one violation mark if Y/Z is not at the right edge of the prosodic word"—then ALIGN-Y-R and ALIGN-Z-R would not be able to differentiate between the candidates which displace Y and Z from the right edge. That is to say, the MP-violating candidate (6e) would be indistinguishable from the MP-obeying and desired candidate (6f). Under categorical definitions, both candidates would incur single violations of both constraints, because, in both candidates, neither Y nor Z is at the right edge. The two candidates would thus have identical violation profiles, and the MAP would not be able to choose between them. This would invalidate the MAP's ability to generate the MP. Therefore, in order to adopt the MAP as a framework for morpheme ordering, alignment constraints must be defined gradiently.

Before proceeding, a few words must be said regarding the use of c-command in the definition of the MAP. Evidence from Arabic to be presented in Sect. 4 will demonstrate that the MAP must be calculated over a (post-)syntactic structure that includes the results of head movement, i.e., complex-head structures like (5b) rather than base-generated syntactic structures like (5a). As such, the version of c-command employed here—which is stated in (8) below—must treat the lowest segment of a terminal node as a distinct object from any higher segments. Otherwise, in certain cases, we might not have the necessary (non-)dominance relations (Kayne 1994) to effectuate c-command.[1]

[1]Thanks to Gereon Müller for pointing this out to me. This adjustment would not be necessary if the MAP were calculated over the base-generated syntactic structure.

Table 1 Types of c-command relations

	Type of c-command	α c-commands β?	β c-commands α?
a.	*Asymmetric*		
	α asymmetrically c-commands β	yes	no
	β asymmetrically c-commands α	no	yes
b.	*Symmetric*		
	α and β symmetrically c-command each other	yes	yes
c.	*None*		
	Neither α nor β c-command the other	no	no

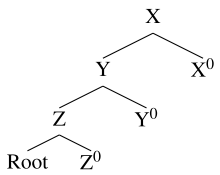
(8) Working definition of c-command
A terminal node α *c-commands* a terminal node β iff the lowest segment of α is sister to the lowest segment of β or a constituent that contains the lowest segment of β.

This definition of c-command (as any definition would) yields three possible relations between two heads: asymmetric c-command (Table 1, a), symmetric c-command (Table 1, b), and the absence of c-command (Table 1, c). The MAP is defined over *asymmetric* c-command relations because asymmetric c-command reliably correlates with relative structural height.

2.3 Alignment ranking in the absence of asymmetric c-command

The Mirror Alignment Principle establishes the ranking of alignment constraints whose terminals stand in asymmetric c-command relations. But what happens when two terminals do not stand in an asymmetric c-command relation, i.e. Table 1, (b) and (c)? Consider again the schematic complex head structure from (5b), repeated in (9). In complex heads, the lowest two terminals stand in *symmetric* c-command, not *asymmetric* c-command.

(9) Complex head structure of /Root, X, Y, Z/



Since X^0 asymmetrically c-commands Y^0, Z^0, and Root, the MAP asserts that Align-X must outrank all the other terminals' alignment constraints. Similarly, since Y^0 asymmetrically c-commands both Z^0 and Root, Align-Y must dominate Align-Z and Align-Root. However, since Z^0 and Root stand in *symmetric c-command*, the MAP does not establish a ranking between Align-Z and Align-Root. The MAP thus generates the alignment ranking in (10).

In the event that the direction of alignment for Align-Root were *left*, the lack of a MAP-enforced ranking between Align-Root and Align-Z would pose no problem for the MP: the Root would go farther to the left and Z would go farther to the right, avoiding any conflict. However, if the direction of alignment for ALIGN-ROOT is instead *right*, matching the orientation of the affixes' alignment constraints, conflict arises, as shown in (10). The tableau in (10) newly considers candidate orders where Root is displaced from the left-edge. What we find is that, in the absence of a MAP-prescribed ranking between ALIGN-ROOT-R and the lowest-ranked affixal alignment constraint, ALIGN-Z-R, we predict variation in which of those two morphemes surfaces further to the right:

(10) Ranking indeterminacy at the bottom of a complex head

i. *Ranking*: ALIGN-X-R ≫ ALIGN-Y-R ≫ ALIGN-Z-R, ALIGN-ROOT-R

ii. *Tableau*:

/Root, X, Y, Z/	ALIGN-X-R	ALIGN-Y-R	ALIGN-Z-R	ALIGN-RT-R
a. ☞ Root-Z-Y-X		*	**	***
b. ☞ Z-Root-Y-X		*	***	**
c. Root-Y-Z-X		**!	*	***
d. Root-Z-X-Y	*!		**	***

The top-ranking of ALIGN-X-R rules out any candidate output like (10d) where X is not the rightmost morpheme. ALIGN-Y-R is next highest ranked; so, among all remaining candidate orders (i.e. those with X at the right edge), this eliminates any which does not have Y immediately preceding X, here represented by (10c). But, because of the ranking indeterminacy brought about by the symmetric c-command at the bottom of the complex head, the MAP alone cannot adjudicate between the remaining candidate orders (10a) and (10b), which instantiate the two possible orderings of Root and Z at the left edge. As far as the MAP is concerned, both orders are equally harmonic. Something other than the MAP must therefore be responsible for resolving this indeterminacy.

While other approaches may be feasible, in this paper, I will assume that a language-specific default constraint ranking asserts itself just in case the MAP provides no contradictory ranking. Under this approach, we can view the MAP as demanding "re-ranking" of particular pairs of alignment constraints based on individual morphosyntactic derivations. In Sect. 4, I will show that positing a language-specific default high-ranking of the Root's alignment constraint can capture a coherent set of otherwise arbitrary ordering alternations in Arabic. This sort of language-specific default ranking might also be implicated in the analysis of the "CARP template" in Bantu, which will be examined in Sect. 3.

2.4 Local summary

This section has demonstrated that the Mirror Principle can be implemented in a framework that handles morpheme ordering in the phonological component using alignment constraints, as long as there is a connection which links hierarchical morphosyntactic structure to the ranking of those alignment constraints. This causal link between hierarchical structure and alignment ranking is an algorithm here termed the Mirror Alignment Principle (MAP). The MAP limits the overgeneration problem typically associated with a Generalized Alignment approach to morpheme ordering, because it eliminates (in the general case) the possibility of free ranking of alignment constraints, in contradistinction to (most) other phonological constraints.

While the phonology does ultimately determine the surface order of morphemes, this determination is non-arbitrary; syntactic structure is responsible for providing this information to the phonology. Therefore, under this proposal, we can view the syntax/morphology as making the *decision* about morpheme ordering, and phonology as simply being responsible for the *implementation* of this decision. Since the final determination of order is made in the phonology, this implementation may be imperfect from the perspective of the syntax/morphology, as we predict that other phonological constraints may interact with the MAP-determined alignment constraints in a way that obscures the underlying structures.

This framework, though developed independently, bears significant resemblance to a proposal by Potter (1996), whereby morpheme order is determined in the phonology through the interaction of competing alignment constraints whose relative ranking is non-arbitrarily determined in relation to the syntax. For Potter, the non-arbitrary link is "Hierarchy Correspondence":

(11) Hierarchy Correspondence (Potter 1996:297)
With respect to inflection, the dominance relationships within the syntactic functional hierarchy mirror the dominance relationships within the alignment constraint hierarchy at PF.

The main point of difference between the two approaches, though relatively small, is the following. Potter rejects the notion that morphologically complex words are built up through head movement/adjunction; instead, morphosyntactic feature values are present lexically and simply "checked" in the course of the derivation. As such, the "functional hierarchy" need not necessarily reflect the syntactic derivation, *per se*. This indirect relationship between morphology and syntax contrasts with the direct relationship assumed in the MAP approach. In the following sections, using evidence primarily from verbal derivational morphemes, rather than the purely inflectional morphemes examined by Potter, I will show that the MP—whether implemented by the MAP or by some other means—must truly be tracking syntactic derivation rather than some abstract functional hierarchy, since contrastive semantic/syntactic derivations result in contrasting ordering facts.[2]

3 Mirror-image morpheme orders and the CARP template in Bantu

The Bantu languages represent a banner case of Mirror Principle behavior. Many Bantu languages display mirror-image orderings between the same verbal derivational morphemes ("verbal extensions"), where the ordering alternations correlate directly with a reversal in semantic scope (e.g., Abasheikh 1978; Kimenyi 1980; Baker 1985, 1988a,b; Alsina and Mchombo 1990, 1993; Hyman and Mchombo 1992; Alsina 1999; Simango 1999; Hyman 2003; Mchombo 2004; Good 2005;

[2]One other difference is that Potter uses opposite-edge alignment constraints, where the affix is the first argument of the constraint and the Root is the second argument, to derive the basically parametric difference between ordering in Apache and SiSwati. This is not something that is needed for the data examined in this paper, and thus is something which would be ideally eliminated from the theory on the grounds of parsimony, but this is an empirical question.

McPherson and Paster 2009; Ngoboka 2016; Zukoff 2017b; and many more). I demonstrate in Sect. 3.1, using data from Chichewa, that these types of alternations can be derived using the MAP approach to morpheme ordering and linearization.

While these sorts of MP-obeying mirror-image orderings are common in Bantu, they are just one piece of a more complex picture. In Bantu, the drive for MP-satisfaction sometimes conflicts with the so-called “CARP template” (Hyman 2003; Good 2005), a preference for certain verbal derivational morphemes to appear in a particular order: CAUSATIVE-APPLICATIVE-RECIPROCAL-PASSIVE (C-A-R-P). This conflict manifests itself in different ways across different languages and in different corners of individual languages. In Sects. 3.2 and 3.3, I focus on one particular type of Mirror Principle-CARP template interaction: “asymmetric compositionality” (Hyman 2003:250), as instantiated in Chichewa. Section 3.4 considers additional facts relating to suffix doubling patterns that interact with this system.

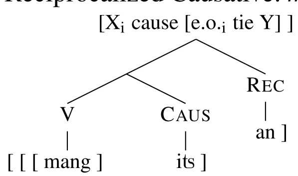
It is not the goal of this section to provide a definitive explanation of the CARP template, or morphological templates generally. Rather, I simply aim to show that the Mirror Alignment Principle approach to morpheme ordering is capable of capturing the contingent compliance vs. violation of the MP as instantiated by this well-known case of templatic morphology. Furthermore, I will show that the MAP is flexible enough to allow for explanations of templatic morphology at various stages of the grammatical derivation, i.e., in the syntax, in the morphology, or in the phonology—all of which have been proposed in the literature. In other words, this section is meant to be a “proof of concept” that the MAP is sufficient to enforce MP-compliance in a real system.

3.1 Mirror-image morpheme orders in Chichewa

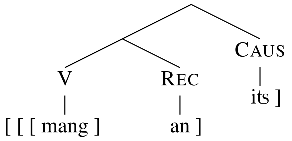
In certain Bantu languages, given two meaningful elements in verbal derivation, such as Causative and Reciprocal, a reversal in semantic interpretation correlates with a reversal in the linear order of the morphemes that expone those meanings (e.g. Baker 1985; Hyman and Mchombo 1992; Hyman 2003; Mchombo 2004). This can be seen with the following contrast from Chichewa. When the Reciprocal meaning scopes over that of the Causative (12a), the Reciprocal morpheme *-an-* is more external in the linear order than the Causative morpheme *-its-*. On the other hand, when the Causative meaning scopes over the Reciprocal meaning (12b), that order is reversed and Causative *-its-* is most external.

(12) Orders of Causative and Reciprocal in Chichewa (Hyman and Mchombo 1992:350; Hyman 2003:247)

a. Reciprocalized Causative: *mang-its-an-* ‘cause each other to tie’



b. Causativized Reciprocal: *mang-an-its-* 'cause to tie each other'
[X cause [Y_i tie e.o.$_i$]]



When the MAP algorithm receives these two distinct structures (the complex heads resulting from head movement), it generates two distinct rankings, as shown in (13) below. These verbal derivational morphemes are suffixal in Chichewa (and the other Bantu languages), so they have right-oriented alignment constraints, as defined in (14). Note that alignment violations are assigned based on *segments*, unlike the schematic examples in Sect. 2, where alignment violations were effectively assigned based on morphemes. While either method would be sufficient for Chichewa, segment-based alignment, which is the standard (McCarthy and Prince 1993; cf. Hyde 2012), will be crucial for the analysis of Arabic in Sect. 4. Hence, segment-based alignment violations will be employed in all remaining tableaux.

(13) Mirror Alignment Principle rankings for the structures in (12)

a. Reciprocalized Causative (12a):
Rec c-commands Caus → Align-Rec-R ≫ Align-Caus-R

b. Causativized Reciprocal (12b):
Caus c-commands Rec → Align-Caus-R ≫ Align-Rec-R

(14) Alignment constraints for Chichewa verbal extensions

a. **Align(Reciprocal, R; PWd, R)** [Align-Rec-R]
Assign one violation for each segment intervening between the right edge of the exponent of Reciprocal and the right edge of the word.

b. **Align(Causative, R; PWd, R)** [Align-Caus-R]
Assign one violation for each segment intervening between the right edge of the exponent of Causative and the right edge of the word.

When these rankings are submitted to the phonological component, they will generate mirror-image orders, as demonstrated in (15) and (16). As mentioned earlier, in the input, the morphemes are linearly unordered; therefore, the order in which they are listed graphically is purely arbitrary. In this section, I omit the Root's alignment constraint from tableaux. The Root is always the leftmost morpheme (among those being considered), and the verbal extensions are clearly right-oriented. Therefore, the facts are consistent either with a left-oriented Align-Root constraint, regardless of its ranking, or a right-oriented Align-Root constraint that ranks below the affixes' alignment constraint. Since this section is only concerned with the relative order of the verbal extension suffixes, I leave the Root's behavior as a question for future research. The (c) and (d) candidates are included to illustrate the harmonic bounding properties of gradient alignment.

(15) Reciprocalized Causative: *mang-its-an-* (12a)

/mang$_{ROOT}$, its$_{CAUS}$, an$_{REC}$/			ALIGN-REC-R	ALIGN-CAUS-R
a.	☞	mang-its-an-		** (an)
b.		mang-an-its-	*!* (its)	
c.		its-mang-an-		**, *!*** (an, mang)
d.		an-mang-its-	*!*, **** (its, mang)	

(16) Causativized Reciprocal: *mang-an-its-* (12b)

/mang$_{ROOT}$, its$_{CAUS}$, an$_{REC}$/			ALIGN-CAUS-R	ALIGN-REC-R
a.		mang-its-an-	*!* (an)	
b.	☞	mang-an-its-		** (its)
c.		its-mang-an-	*!*, **** (an, mang)	
d.		an-mang-its-		**, *!*** (its, mang)

In the derivation of the Reciprocalized Causative in (15), the highest ranked constraint is ALIGN-REC-R. This constraint eliminates all candidate orders which do not place the right edge of the Reciprocal morpheme (the [n] of *an*) at the right edge of the word, i.e. candidates (b) and (d).[3] The next highest ranked constraint is ALIGN-CAUS-R. This constraint selects from among the remaining candidate orders the one where the right edge of the Causative morpheme (the [ts] of *its*) is as far to the right as possible, i.e. interior to the Reciprocal morpheme but no farther—candidate (a) over candidate (c). When the MAP produces the opposite ranking for the Causativized Reciprocal in (16), the candidate set and violation profiles are identical, but the constraint ranking instead selects candidate (b).

This demonstrates again that alignment constraints can correctly order morphemes in the phonological component *without* the application of declarative concatenation operations at any point within the grammar, as in standard approaches (e.g. Baker 1985, 1988a; Embick 2007, 2015; Yu 2007). This will be desirable for the analysis of Arabic root-and-pattern morphology pursued in Sect. 4, as well as other instances of nonconcatenative morphology in general. All that is required is that hierarchical relations in the syntax/morphology are transmitted to the phonology as a set of pairwise ordered rankings of alignment constraints, via the MAP.

3.2 The CARP template and asymmetric compositionality

While a number of Bantu languages do indeed display behaviors like those introduced above for Chichewa, the full picture is a great deal more complicated. Hyman (2003:247–248) outlines several ways in which the Bantu languages violate the MP in order to satisfy the CARP template (see also, e.g., Hyman and Mchombo 1992; Good 2005); that is to say, instances in which the languages linearize Causative (C), Applicative (A), Reciprocal (R), and Passive (P) in that order even when it contradicts the order expected by the MP.

[3]Note that these verb forms require "final vowel" suffixes, so the rightmost CARP element will never be absolute word-final. We can handle this by including a right-oriented alignment constraint for the final vowel morpheme that outranks the verbal extensions' alignment constraints. This is totally consistent with the MAP, as the final vowel morphemes expone Tense/Aspect/Mood information (see, e.g., Nurse and Philippson 2006), which we would expect to be morphosyntactically higher than valence-changing heads. This interaction is further evidence that the alignment constraints must be evaluated gradiently.

Table 2 Asymmetric compositionality with Chichewa's Causative and Reciprocal

Semantic Interpretation	**Surface Morpheme Order**					
	CARP-obeying			CARP-violating		
	ROOT-CAUS-REC *mang-its-an*			ROOT-REC-CAUS *mang-an-its*		
[[[ROOT] CAUS] REC]	a.	✓	(MP-obeying)	b.	✗	(MP-violating)
[[[ROOT] REC] CAUS]	c.	✓	(MP-violating)	d.	✓	(MP-obeying)

First and most basically, some Bantu languages obey the CARP template at all costs. For example, Chimwiini (Abasheikh 1978:28; Hyman 2003:258) and Kinyarwanda (Kimenyi 1980; Banerjee 2019), and perhaps Luganda (McPherson and Paster 2009), show no mirror-image orders with CARP elements. Insofar as they allow semantic scopal reversals like those discussed above for the Causative and Reciprocal in Chichewa, the distinct syntactic structures underlying the distinct scopal interpretations are invariably mapped to the same CARP-obeying linear order.

Second, among those languages that do show mirror-image ordering behavior, mirror-image orders are generally only permitted with certain pairs of suffixes, rather than as a whole throughout the system. For example, while Chichewa allows mirror-image orderings between Causative and Reciprocal, it *does not* allow mirror-image orders between Causative and Applicative or Applicative and Reciprocal (Hyman and Mchombo 1992; Hyman 2003; Mchombo 2004). In both of those cases, both scopal interpretations are mapped invariably to the CARP-obeying linear order.

Thirdly and most interestingly, there is an interpretive asymmetry within this system, which Hyman (2003:250) terms "asymmetric compositionality" (see also Mchombo 2004). In languages which do permit mirror-image orderings, the CARP-obeying order permits *both scopal interpretations* while the CARP-violating order permits only the one correlated with the surface order via the MP (Hyman 2003:248; Good 2005). Put another way, in Bantu, CARP-*obeying* orders are (in most if not all cases) semantically ambiguous, while CARP-*violating* orders are never semantically ambiguous. Chichewa's Causative and Reciprocal display this type of asymmetric compositionality.

The asymmetric compositionality illustrated by Chichewa's Causative and Reciprocal is summarized in Table 2. A "✓" indicates an order-interpretation (O-I) pair which is licit in Chichewa; a "✗" indicates an O-I pair which is illicit in Chichewa.

From this table, we can draw two generalizations about the nature of asymmetric compositionality:

- First, O-I pairs that *obey the MP* (i.e., where semantic interpretation correlates with linear order) are licit, whether the order is CARP-obeying (Table 2, a) or CARP-violating (Table 2, d). Hence, any licit surface form can be interpreted with the outer affix taking semantic scope over the inner affix.
- Second, O-I pairs where the *linear order is CARP-obeying* are licit, whether correlated with semantic interpretation via the MP (Table 2, a) or not (Table 2, c). Hence, linearly CARP-obeying orders are semantically ambiguous.

Taken together, this shows that there are two conditions which license an O-I pair in such cases: (i) MP-satisfaction, or (ii) linear CARP satisfaction. The only illicit O-I pair is Table 2 (b), the one which satisfies neither of these conditions: it is not MP-obeying, nor is it linearly CARP-obeying.

The way to distinguish a language like Chimwiini (no mirror-image orders) from a language like Chichewa (specific mirror-image orders), is whether MP-satisfaction is sufficient to license an O-I pair. If MP-satisfaction is not sufficient, an O-I pair like Table 2 (d) will not be licensed, and the system will map to a Chimwiini-type language, where only CARP-obeying orders are allowed. The same can be said of different CARP combinations within a language like Chichewa which allows certain mirror-image orderings but not others. That is, in Chichewa, the MP is able to license the CARP-violating order with Causative and Reciprocal, but it is not sufficient to license the CARP-violating order with Causative and Applicative.

Explanation(s) of CARP thus must be able to handle several different situations. They must be able to derive languages that fully obey CARP. They must be able to derive languages with limited MP-driven violation of CARP. And they must be able to derive asymmetric compositionality, where CARP-violating orders correspond to a unique semantic interpretation but CARP-obeying orders can correspond to two distinct semantic interpretations (i.e., are semantically and syntactically ambiguous).

3.3 CARP and the MAP

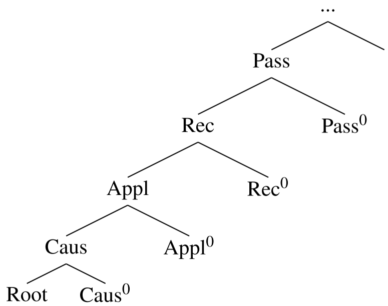
Since CARP effects involve all aspects of the grammar (semantics, syntax, morphology, and phonology), one could reasonably seek to locate the explanation of the CARP template in any grammatical component(s). In the remainder of this section, I entertain several different types of explanations for the CARP template and its interaction with the MP, and show how the MAP is able to generate MP-compliance and asymmetric compositionality in concert with any of these types of explanations.

3.3.1 CARP in the syntax: Syntactic selection

Some recent accounts have sought to explain aspects of the CARP template as selectional restrictions on the syntactic heads involved in CARP (e.g. Myler 2021; Myler and Mali 2021; see also Myler 2015 for a syntactic selectional approach to similar templatic phenomena in Quechua.) For example, Banerjee (2019) shows that syntactic and semantic properties of CARP elements and other heads in the verbal domain may be able to account for Kinyarwanda's full-scale adherence to the CARP template. According to Banerjee, semantically CARP-violating structures can only be realized through periphrasis. This implies that Kinyarwanda does not actually show asymmetric compositionality, suggesting that Kinyarwanda's CARP system may be substantially different than that of Chichewa and other languages that allow some degree of CARP violation.

In any event, if this sort of syntactic approach is an appropriate analysis of CARP, for Kinyarwanda or more generally, then the MAP would have no problem generating the correct morpheme order. If the syntax is limited to hierarchical structures where elements further to the right in the CARP acronym necessarily asymmetrically c-command elements further to the left (schematized in (17)),[4] and they all have right-oriented alignment constraints, then the MAP will automatically generate the rankings necessary to derive CARP (shown in (18)).

(17) CARP-obeying tree structure



(18) MAP-determined rankings for (17)

a. Pass^0 c-commands Rec^0 → ALIGN-PASS-R ≫ ALIGN-REC-R
b. Rec^0 c-commands Appl^0 → ALIGN-REC-R ≫ ALIGN-APPL-R
c. Appl^0 c-commands Caus^0 → ALIGN-APPL-R ≫ ALIGN-CAUS-R
⇒ ALIGN-PASS-R ≫ ALIGN-REC-R ≫ ALIGN-APPL-R ≫ ALIGN-CAUS-R

This reiterates that, whenever the syntax furnishes a hierarchically CARP-obeying structure, the MAP will faithfully realize the CARP order. However, the existence of asymmetric compositionality shows that there are some linearly CARP-obeying forms whose underlying syntactic structure does not conform to the hierarchy in (17). Additionally, consider the following piece of syntactic evidence adduced by Hyman (2003:260, citing Sam Mchombo, p.c.): in Chichewa, there are *extraction asymmetries* between the arguments of semantically ambiguous verb forms whose exponents are linearly CARP-obeying.

As mentioned earlier, in Chichewa, Causative and Applicative always surface in that order (linearly CARP-obeying). When this order corresponds to an Applicativized Causative interpretation (C < A), and gets passivized, only the Applicative argument can be promoted to subject, as shown in (19). On the other hand, when this order corresponds to a Causativized Applicative interpretation (C > A), and gets passivized, only the Causee can be promoted to subject, as shown in (20).

(19) Applicativized Causatives in Chichewa (Hyman 2003:260, ex. 22)

a. Mchómbó a-ná-líl-[CAUS **its**]-[APPL **il**]-a [CAUSEE aná] [INSTR ndodo]
‘Mchombo made the children cry with a stick’

b. [INSTR ndodo] i-ná-líl-[CAUS **its**]-[APPL **il**]-[PASS idw]-á [CAUSEE aná]
‘a stick was used to make the children cry’

c. ?*[CAUSEE aná] a-ná-líl-[CAUS **its**]-[APPL **il**]-[PASS idw]-á [INSTR ndodo]
‘the children were made to cry with a stick’

[4] Note that Banerjee’s (2019) syntactic analysis of Kinyarwanda is significantly more sophisticated than this tree suggests. The tree is meant for expositional purposes only.

(20) Causativized Applicatives in Chichewa (Hyman 2003:260, ex. 23)

a. Mchómbó a-ná-lím-[CAUS **its**]-[APPL **il**]-a [CAUSEE aná] [INSTR makásu]
'Mchombo made the children cultivate with hoes'

b. [CAUSEE aná] á-ná-lím-[CAUS **its**]-[APPL **il**]-[PASS idw]-á [INSTR makásu]
'the children were made to cultivate with hoes'

c. ?*[INSTR makásu] á-ná-lím-[CAUS **its**]-[APPL **il**]-[PASS idw]-á [CAUSEE aná]
'hoes were used to make the children cultivate'

These facts indicate that only the argument that is syntactically highest is available for movement to subject. This requires that the arguments, and, correspondingly, the heads that introduce them, be merged in different syntactic orders for the two different scopal interpretations. Thus, there must be distinct syntactic structures underlying the ambiguous surface form of the verb word.

Another suggestive piece of evidence comes from idioms (Hyman and Mchombo 1992; Hyman 2003; Henderson 2019). For example, as shown in (21), in Chichewa, the root *uk-* 'wake up' plus the applicative suffix *-il* combine to create the idiomatic meaning 'rebel against.' This idiomatic meaning is preserved under causativization, even though the applicative is (necessarily) no longer adjacent to the root, due to the CARP requirement. Under the standard assumption that syntactic locality is required in order to generate idiomatic meaning (Marantz 1997; Arad 2003), the root and the applicative must still be adjacent in the syntax despite their non-adjacency in the linear output.[5]

(21) Lexicalized APPL + CAUS in Chichewa (Hyman 2003:264; from Hyman and Mchombo 1992)

a. *uk-* 'wake up'
b. *uk-il-* 'rebel against'
c. **uk-il-its-* 'cause to rebel against'
d. *uk-its-il-* 'cause to rebel against'

Therefore, in Chichewa at least, the explanation for CARP, either in part or in full, must lie somewhere in the imperfect mapping between syntactic structure and the surface order of morphemes, i.e., *after* the narrow syntax. Assuming the "Y-model" of the grammar (Chomsky 1986 *et seq.*), where the narrow syntax feeds separate PF and LF derivations, this likewise rules out a (purely) semantic explanation of linear CARP effects.

3.3.2 CARP in the morphology: Post-syntactic operations

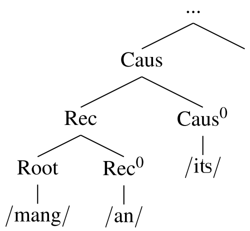
We now know that the syntax can output a hierarchical structure that, if fed into the MAP, would yield a CARP-violating order. We also know, because of asymmetric compositionality, that this structure can nonetheless be mapped onto a CARP-obeying order as well. The next logical explanation is one where the hierarchical structure can be reshaped by the morphological component, such that the MAP can operate transparently on that mutated structure to generate a CARP-obeying order. This is possible

[5] Donca Steriade (p.c.) raises the following concern regarding this example: if we were to instead ascribe to *uk-* a translation 'rise up,' it is less clear that the suffixed derivatives truly have an idiomatic meaning at all. If this is correct, then it is less clear that this example constitutes evidence in favor of an underlying CARP-violating structure.

if we follow Distributed Morphology (Halle and Marantz 1993) and allow morphological operations to apply to syntactic structure prior to submission to phonology (e.g. Embick and Noyer 2001; Arregi and Nevins 2012; Harizanov and Gribanova 2019; cf. Trommer 2001).

Consider the syntactic structure of a Causativized Reciprocal, shown in (22) below (adapted from (12b)). As discussed above, this structure can be realized in either of two ways: (23a) *mang-its-an-*, which obeys CARP but violates the MP; or (23b) *mang-an-its-*, which violates CARP but obeys the MP. If the MAP applies to the structure in (22) and nothing else intercedes, the phonology will output the MP-obeying form (23b). If, though, we want the MAP to generate (22a) while applying transparently to the output of the morphological component, we need some morphological operation to create a CARP-obeying structure (cf. Ryan 2010:778).

(22) Syntactic structure of a Causativized Reciprocal ('cause to tie each other')

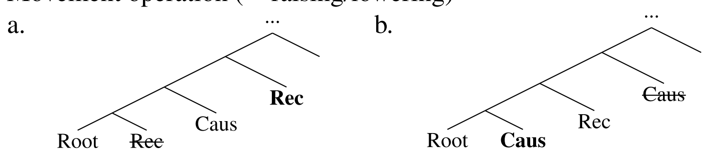


(23) Linear orders of a Causativized Reciprocal

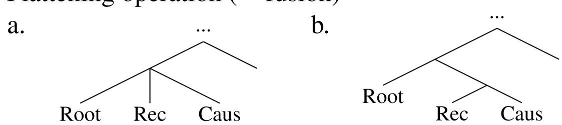
a. *mang-its-an-* [ROOT-CAUS-REC] (CARP-obeying, MP-violating)
b. *mang-an-its-* [ROOT-REC-CAUS] (CARP-violating, MP-obeying)

The simplest such solution is one which transforms the tree in (22) into one which is fully syntactically CARP-obeying, where Rec asymmetrically c-commands Caus. Theoretically, this could be effectuated by moving one of the heads: either raising the Rec head above the Caus head (24a), or lowering the Caus head below the Rec head (24b). Alternatively, if an operation could remove all asymmetric c-command relations between CARP elements, resulting in some flat structure resembling the trees in (25), this would nullify the MAP's influence on order.

(24) Movement operation (∼ raising/lowering)



(25) Flattening operation (∼ fusion)



We could view these operations as being motivated by morphological markedness constraints (cf. Arregi and Nevins 2012) relating to c-command relations. For the specific pair at hand, this would be the markedness constraint in (26). Under this approach, CARP is the result of a set of such c-command-based morphological markedness constraints involving the CARP elements. Whichever constraints are active in a given Bantu language will (obligatorily or optionally; see below) trigger the morphological operation that transforms syntactically CARP-violating structures into (post-)syntactically CARP-obeying structures. The resulting structures feed the MAP, and generate the linear CARP order transparently.

(26) Morphological markedness constraint
***Caus > Rec**: Causative may not asymmetrically c-command Rec.

If the resulting structure is like (25), there would be no asymmetric c-command relations among CARP elements. The MAP would thus not generate any (relevant) crucial rankings. Without guidance from the MAP, the grammar could revert to its language-specific default ranking, which would be the ranking in (27). Under this approach, this default ranking (fed by the requisite morphological operations) would be the source of the "CARP template." Note that this ranking is the same one that the MAP generates for syntactically CARP-obeying structures (see (18) above).

(27) Language-specific default ranking for Bantu
Align-Pass-R ≫ Align-Rec-R ≫ Align-Appl-R ≫ Align-Caus-R

Operations like these, potentially paired with morphological markedness constraints like (26) and/or the default ranking in (27), are sufficient to generate asymmetric compositionality, if we assume that they apply *optionally*. That is to say, given a syntactically CARP-violating structure: when the operation *applies*, the CARP-obeying, MP-violating order is generated; when the operation *fails to apply*, the CARP-violating, MP-obeying order is generated. In languages or constructions which only tolerate the CARP-obeying order, the operation is *obligatory*. This shows that the MAP is consistent with an approach to CARP, and perhaps templatic morphology more generally, located in the morphological component of the grammar.

To be clear, this subsection is meant to lay out the contours of an analysis based on morphological operations. In the absence of a restrictive theory of morphological operations—and, for that matter, morphological markedness constraints and language-specific default rankings—this analysis has a strongly *ad hoc* and unrestrictive character (cf. Ryan 2010:778–779). For this reason, an analysis located in the phonology may prove to be more appealing.

3.3.3 CARP in the phonology: Bigram morphotactic constraints

Lastly, let us consider how the MAP could interact with an approach to CARP located in the phonological component. If syntactically CARP-violating structures proceed through the morphological derivation unaltered, the MAP will unequivocally advocate for the linearly CARP-violating order in the phonology. However, alignment constraints interact with, and can indeed be outranked and thus overridden by, other phonological constraints (see Sect. 4). Therefore, if we can formulate phonological constraints that advocate for the CARP order, we can still generate the desired order-

Table 3 Ryan's ordering typology (Ryan 2010:761, Table 1)

	Scenario	Ranking	Output(s) for /[[[Root]X]Y]/	Output(s) for /[[[Root]Y]X]/
i.	Compositional	SCOPE ≫ X-Y , Y-X	Root-X-Y	Root-Y-X
ii.	Fixed (a)	X-Y ≫ SCOPE , Y-X	Root-X-Y	Root-X-Y
	Fixed (b)	Y-X ≫ SCOPE , X-Y	Root-Y-X	Root-Y-X
iii.	Asymmetric (a)	X-Y ∼ SCOPE ≫ Y-X	Root-X-Y	Root-X-Y, Root-Y-X
	Asymmetric (b)	Y-X ∼ SCOPE ≫ X-Y	Root-X-Y, Root-Y-X	Root-Y-X
iv.	Free	X-Y ∼ Y-X ≫ SCOPE	Root-X-Y, Root-Y-X	Root-X-Y, Root-Y-X

ing facts. To this end, I will explore Ryan's (2010) "bigram morphotactic constraints" as a means of integrating CARP and the MAP in the phonology.[6]

Note that one could consider locating this sort of analysis in an autonomous, constraint-based morphological component of the sort seemingly envisioned by, for example, Trommer (2001); Hyman (2003); and Ryan (2010). However, the analysis of suffix doubling in Sect. 3.4 below requires the bigram morphotactic constraints to interact transparently with explicitly phonological faithfulness constraints. Additionally, in the analysis of Arabic in Sect. 5, I will show that the MAP-based alignment constraints also interact transparently with phonological markedness constraints. Since both constraint types involved in this analysis interact transparently with phonological constraints, it stands to reason that these constraints operate in the phonological module.

Ryan (2010) shows that (seemingly) arbitrary ordering properties like CARP can be modeled using bigram morphotactic constraints. These are constraints that prefer (immediate) precedence relations between particular morpheme pairs. For example, the requirement that Applicative follow Causative in the CARP template would be effectuated by a constraint CAUS-APPL (Ryan 2010:778), which assigns violations for every instance of Causative which is not immediately followed by Applicative:

(28) Example bigram morphotactic constraint (following Ryan 2010)
CAUS-APPL: Assign one violation for every exponent of Causative which is not immediately followed on the surface by an exponent of Applicative.

Ryan identifies a typology consisting of four ordering scenarios which can arise based on the interaction between bigram constraints and a constraint advocating for the MP (for which he uses Rice's 2000 semantics-based SCOPE constraint). These are enumerated in Table 3, where X-Y and Y-X represent both possible bigram constraints for each pair of morphemes, "≫" indicates strict ranking domination, and "∼" indicates variable ranking. I depart slightly from Ryan's notation in using " , " to indicate non-crucial ranking (in type (i) and type (ii)), so as to distinguish it from meaningfully variable ranking (in type (iii) and type (iv)).

[6] This approach bears some similarities to Hyman's (2003) analysis, where a set of violable pairwise MIRROR constraints compete with a unitary TEMPLATE constraint that prefers the CARP order. However, since the MAP generates MP effects indirectly through the transmission of syntactic structure into the phonology, the MAP is not compatible with Hyman's approach.

Chichewa's Causative and Reciprocal instantiate a type (iii) asymmetric ordering scenario. Elsewhere in Chichewa, Causative and Applicative, and Applicative and Reciprocal, always surface in the CARP order (Hyman 2003; Mchombo 2004). This means that they each represent a type (ii) fixed ordering scenario. In the MAP framework, the function of SCOPE is handled by the MAP-driven ranking of alignment constraints (shorthanded as MAP in (29)). Replacing SCOPE with the MAP constraints within Ryan's ranking schema (more on this below), and substituting the relevant morphemes, we arrive at the following rankings for the constraints determining the relative order of Causative, Applicative, and Reciprocal in Chichewa:

(29) Chichewa bigram + MAP-driven alignment rankings

a.	Asymmetric:	CAUS-REC	∼	MAP	≫	REC-CAUS
b.	Fixed:	CAUS-APPL	≫	MAP	,	APPL-CAUS
c.	Fixed:	APPL-REC	≫	MAP	,	REC-APPL

The phonological derivations of the fixed ordering cases (29b, 29c) are straightforward. The dominant bigram constraint—CAUS-APPL and APPL-REC, respectively—is decisive in the evaluation, masking any effects of the MAP and of any potential lower-ranked variation. (In these cases, we have no evidence for relative ranking between the lower-ranked bigram constraint, such as APPL-CAUS in (30) below, and the MAP constraints, either as a block or as individual constraints.) This is illustrated in (30) for Causative and Applicative, where we see that alternations in syntactic structure, feeding alternations in the MAP ranking, have no effect on ordering: undominated CAUS-APPL always selects the Causative-Applicative order *mang-its-il-*.

(30) Fixed ordering of Causative and Applicative (consistent CARP order)

i. Applicativized Causative *mang-its-il-* (MP-obeying):

MAP ranking: ALIGN-APPL-R ≫ ALIGN-CAUS-R

[[[Root]Caus]Appl] /mang$_{ROOT}$, its$_{CAUS}$, il$_{APPL}$/	**Bigram 1**	**MAP constraints**		**Bigram 2**
	CAUS-APPL	ALIGN-APPL-R	ALIGN-CAUS-R	APPL-CAUS
a. ☞ mang-its-il- [CA]			** (il)	*
b. mang-il-its- [AC]	*!	** (its)		

ii. Causativized Applicative *mang-its-il-* (MP-violating):

MAP ranking: ALIGN-CAUS-R ≫ ALIGN-APPL-R

[[[Root]Appl]Caus] /mang$_{ROOT}$, its$_{CAUS}$, il$_{APPL}$/	**Bigram 1**	**MAP constraints**		**Bigram 2**
	CAUS-APPL	ALIGN-CAUS-R	ALIGN-APPL-R	APPL-CAUS
a. ☞ mang-its-il- [CA]		** (il)		*
b. mang-il-its- [AC]	*!		** (its)	

Unlike the fixed ordering scenarios, the asymmetric ordering scenario represented by Causative and Reciprocal allows us to see how the MAP constraints operate within the bigram approach to CARP. The crucial point is the *variable* ranking between the dominant bigram constraint and the MAP constraints in (29a). Whereas SCOPE—the constraint motivating MP-compliance in Rice (2000) and Ryan (2010)—is a unitary constraint, the MAP motivates MP-compliance through the ranking and interaction of multiple constraints. This complicates the structure of the ranking variation in (29a), where that variation has substantive effect, leading to asymmetric compositionality.

A natural interpretation of this variation would be to posit partial ordering among the constraints (Anttila 1997a,b, 2002 *et seq.*), which would work as follows.[7] Assume that, in asymmetric ordering scenarios like Causative and Reciprocal, the dominant bigram constraint (here, CAUS-REC) is "underlyingly" unranked with respect to any of the MAP-driven alignment constraints (here, ALIGN-CAUS-R and ALIGN-REC-R). Likewise, in all instances, the alignment constraints are underlyingly unranked with respect to each other. This results in the mutually unranked set of constraints in (31):

(31) Underlyingly mutually unranked constraint set
{ALIGN-CAUS-R, ALIGN-REC-R, CAUS-REC}

For any given syntactic derivation, the MAP will generate an order between the relevant alignment constraints. Given a Causativized Reciprocal syntactic input [[[Root]Rec]Caus], the MAP will generate the ranking in (32):

(32) MAP ranking for Causativized Reciprocal [[[Root]Rec]Caus]
ALIGN-CAUS-R ≫ ALIGN-REC-R

For any instance of production of this syntactic input, the grammar selects one of the possible total rankings over the set in (31) that is consistent with the partial ordering dictated by the MAP in (32). There are three such total rankings, shown in (33) along with their unique outputs, as demonstrated in the corresponding tableaux. (I use "|¦|" to indicate an underlying non-ranking from the constraint set in (31) involving the bigram constraint, which has been fixed as such in that given derivation.)

(33) Possible rankings and outputs for [[[Root]Rec]Caus]

i. CAUS-REC ≫ ALIGN-CAUS-R ≫ ALIGN-REC-R ⇒ *Output*: CR

[[[Root]Rec]Caus] /mang$_{\text{ROOT}}$, its$_{\text{CAUS}}$, an$_{\text{REC}}$/	**Bigram 1** CAUS-REC	**MAP 1** ALIGN-CAUS-R	**MAP 2** ALIGN-REC-R	**Bigram 2** REC-CAUS
a. ☞ mang-its-an- [CR]		** (an)		*
b. mang-an-its- [RC]	*!		** (its)	

ii. ALIGN-CAUS-R ≫ CAUS-REC ≫ ALIGN-REC-R ⇒ *Output*: RC

[[[Root]Rec]Caus] /mang$_{\text{ROOT}}$, its$_{\text{CAUS}}$, an$_{\text{REC}}$/	**MAP 1** ALIGN-CAUS-R	**Bigram 1** CAUS-REC	**MAP 2** ALIGN-REC-R	**Bigram 2** REC-CAUS
a. mang-its-an- [CR]	*!* (an)			*
b. ☞ mang-an-its- [RC]		*	** (its)	

iii. ALIGN-CAUS-R ≫ ALIGN-REC-R ≫ CAUS-REC ⇒ *Output*: RC

[[[Root]Rec]Caus] /mang$_{\text{ROOT}}$, its$_{\text{CAUS}}$, an$_{\text{REC}}$/	**MAP 1** ALIGN-CAUS-R	**MAP 2** ALIGN-REC-R	**Bigram 1** CAUS-REC	**Bigram 2** REC-CAUS
a. mang-its-an- [CR]	*!* (an)			*
b. ☞ mang-an-its- [RC]		** (its)	*	

When the dominant bigram constraint CAUS-REC outranks the higher-ranked alignment constraint ALIGN-CAUS-R (33.i), the CARP-obeying, MP-violating output *Root-Caus-Rec* will be generated. On the other hand, when CAUS-REC ranks be-

[7] Thank you to Arto Anttila for suggesting this approach. See Zukoff (2017b) for discussion of alternative conceptions of this variation.

low ALIGN-CAUS-R, whether between the two alignment constraints (33.ii) or below them both (33.iii), the CARP-violating, MP-obeying output *Root-Rec-Caus* will be generated.

This approach correctly predicts the absence of output variation for the reverse syntactic input, a Reciprocalized Causative [[[Root]Caus]Rec], because the higher-ranked alignment constraint in this case, ALIGN-REC-R, pulls in the same direction as the dominant bigram constraint CAUS-REC. This is shown in (34).

(34) Possible rankings and outputs for [[[Root]Caus]Rec]

i. CAUS-REC ≫ ALIGN-REC-R ≫ ALIGN-CAUS-R ⇒ *Output*: CR

[[[Root]Caus]Rec] /mang$_{\text{ROOT}}$, its$_{\text{CAUS}}$, an$_{\text{REC}}$/	**Bigram 1** CAUS-REC	**MAP 1** ALIGN-REC-R	**MAP 2** ALIGN-CAUS-R	**Bigram 2** REC-CAUS
a. ☞ mang-its-an- [CR]			** (an)	*
b. mang-an-its- [RC]	*!	** (its)		

ii. ALIGN-REC-R ≫ CAUS-REC ≫ ALIGN-CAUS-R ⇒ *Output*: CR

[[[Root]Caus]Rec] /mang$_{\text{ROOT}}$, its$_{\text{CAUS}}$, an$_{\text{REC}}$/	**MAP 1** ALIGN-REC-R	**Bigram 1** CAUS-REC	**MAP 2** ALIGN-CAUS-R	**Bigram 2** REC-CAUS
a. ☞ mang-its-an- [CR]			** (an)	*
b. mang-an-its- [RC]	*!* (its)	*		

iii. ALIGN-REC-R ≫ ALIGN-CAUS-R ≫ CAUS-REC ⇒ *Output*: CR

[[[Root]Caus]Rec] /mang$_{\text{ROOT}}$, its$_{\text{CAUS}}$, an$_{\text{REC}}$/	**MAP 1** ALIGN-REC-R	**MAP 2** ALIGN-CAUS-R	**Bigram 1** CAUS-REC	**Bigram 2** REC-CAUS
a. ☞ mang-its-an- [CR]		** (an)		*
b. mang-an-its- [RC]	*!* (its)		*	

This partial ordering approach to the variation in asymmetric compositionality has at least two advantages. First, it allows for the possibility of surface rankings where other types of constraints (here, bigram constraints) are ranked inside the alignment block. This is consistent with findings from Huave (Zukoff 2021c; cf. Kim 2008, 2010), where the phonological faithfulness constraint DEP needs to rank inside the alignment block in order to account for the distribution of affix mobility. Second, under certain assumptions about ranking variation, it makes a testable prediction about the relative frequency of the variable outputs in (33).

Following Kiparsky (1993); Riggle (2010); *a.o*, it is reasonable to assume that the relative frequency of a variable output is proportional to the percentage of licit total rankings that generate that output. Given the syntactic input [[[Root]Rec]Caus], the CARP-obeying output *Root-Caus-Rec* wins in 1/3 of the cases (33.i), whereas the MP-obeying output *Root-Rec-Caus* wins in 2/3 of the cases (33.ii, 33.iii). Assuming that all rankings are equally probable, this would then predict that *Root-Rec-Caus* should be a *more frequent* output than *Root-Caus-Rec* for this syntactic input. Generalizing from this specific case, this implies that MP-satisfying outputs should be preferred to templatic outputs when both are tolerated for a given syntactic input.

Table 4 Permitted orderings of Applicative /il/ + Reciprocal /an/ in Chichewa (Hyman and Mchombo 1992:351ff.; Hyman 2003:253ff.)

			Reciprocalized Applicative [[[Root] Appl] Rec]	Applicativized Reciprocal [[[Root] Rec] Appl]
Single exponents				
a.	APPL-REC (CARP)	*mang-il-an-*	✓ (MP)	✓
b.	REC-APPL	*mang-an-il-*	✗	✗ (MP)
Doubled exponents				
c.	APPL-REC-APPL	*mang-il-an-il-*	✗	✗
d.	REC-APPL-REC	*mang-an-il-an-*	✗	✓

I do not know of any available evidence that bears on this prediction, but this should be testable given appropriate corpus data.

This subsection has demonstrated that combining Ryan's (2010) bigram morphotactic constraints with the MAP *in the phonology* is capable of deriving Hyman's (2003) "asymmetric compositionality," and indeed Ryan's full ordering typology. It does not provide a principled explanation for why we observe the CARP order as the morphotactically preferred order and not some other assemblage of those four morphemes. As per Ryan's typology in Table 3, the bigram constraints for any pair of morphemes are (or at least in principle ought to be) freely rankable: compare, e.g., Fixed (a) vs. Fixed (b) (Table 3, ii). To whatever extent CARP is a non-arbitrary ordering preference, some other factor(s) will need to be brought to bear. I leave this as a question for future work.

3.4 CARP and suffix doubling

There is one additional set of data relating to the CARP system in Chichewa that I will discuss in this section. Table 4 shows the permitted orderings for combinations of Applicative and Reciprocal in Chichewa. As alluded to in (29c) above, when Applicative and Reciprocal both have a single exponent, Applicative always precedes Reciprocal, regardless of the syntactic input. That is to say, these two affixes stand in a "fixed order," to use Ryan's (2010) terminology, which can be motivated by invariably ranking the bigram constraint APPL-REC above the MAP constraints. However, as shown in Table 4 (d), there is one additional realization of these two affixes, just for Applicativized Reciprocals: doubling the Reciprocal /an/ and sandwiching Applicative /il/ in between.

The tableau in (35) below shows that, under certain assumptions about the representation of suffix doubling and about the definition of the bigram constraints, the same constraints that derive fixed order in the absence of doubling (35a) assign the exact same violation profile to the candidate which doubles the Reciprocal (35d). This is a welcome development, because these are exactly the two orders which are attested in Table 4.

(35) Variation in the Applicativized Reciprocal

[[[Root]Rec]Appl] /mang$_{\text{ROOT}}$, il$_{\text{APPL}}$, an$_{\text{REC}}$/	Bigram 1: APPL-REC	MAP constraints: ALIGN-APPL-R	MAP constraints: ALIGN-REC-R	Bigram 2: REC-APPL
a. ☞ mang-il-an- [AR]		** (an)		*
b. mang-an-il- [RA]	*!		** (il)	
c. mang-il-an-il- [ARA]	*!		** (il)	
d. ☞ mang-an-il-an- [RAR]		** (an)		*

The necessary assumptions are as follows. First, we must assume that the two [an] strings in (35d) (and thus likewise the two [il] strings in (35c)) represent a single discontinuous exponent, arising from splitting of a single underlying exponent. This comports with the morphosyntax, where these cases of doubling are purely morpho(phono)logical and not connected to the presence of additional syntactic material. More concretely, this is necessary in order for ALIGN-REC-R to assign the same number of violations, i.e. zero, to both candidate (35a) and candidate (35d). If we assumed that both [an] strings were distinct exponents, candidate (35d) would accrue four violations from the first [an] string, which would harmonically bound it relative to (35a). By assuming that the two [an] strings comprise a single surface exponent, we ensure that ALIGN-REC-R counts only from the second [n].

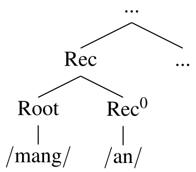
Second, we must slightly refine our definition schema for the bigram morphotactic constraints. Consider again candidate (35d) *mang-an-il-an-*. In order for this candidate to remain on par with the non-doubling candidate (35a), it must not receive an APPL-REC violation. The Applicative exponent [il] clearly precedes material belonging to the Reciprocal exponent /an/; however, assuming that the two [an]s constitute a single discontinuous exponent, it does not precede the entire exponent. Therefore, we require the definition in (36), which now references "a segment belonging to" a particular exponent, rather than the exponent in its entirety. This definition correctly does not assign an APPL-REC violation to (35d) but crucially does assign one to (35b) and (35c) according to the same logic.

(36) Revised bigram constraint definition
APPL-REC: Assign one violation for every exponent of Applicative which is not immediately followed on the surface by *a segment belonging to* an exponent of Reciprocal. (cf. CAUS-APPL (28))

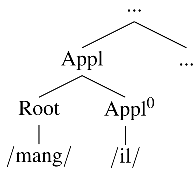
Under these assumptions, we derive the variation between the simple CARP output (35a) and the Reciprocal-doubling output (35d). However, in Table 4, we saw that the doubling output is restricted to the Applicativized Reciprocal, disallowed for the Reciprocalized Applicative. The MAP constraints cannot account for this difference, because, according to the above assumptions, they treat the two winning outputs the same, regardless of their relative ranking. Hyman (2003:256) suggests to resolve this problem by appealing to cyclicity: Table 4 (d) *mang-an-il-an-* is permitted for an Applicativized Reciprocal because it is built from a simple Reciprocal *mang-an-*, where /-an/ is suffixed directly to the Root. The MAP framework takes a radically parallel view of linearization, so it is not compatible with a literally cyclic approach to word building. However, it could be compatible with a pseudo-cyclic Base-Derivative (BD) faithfulness (Benua 1997) analysis of cyclic effects.

Table 5 Base-Derivative structures and suffix doubling

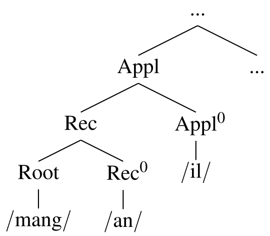
a. **Reciprocal**
mang-an-



b. **Applicative**
mang-il-



c. **Applicativized Reciprocal**
**mang-an-il-* → *mang-an-il-an*



d. **Reciprocalized Applicative**
mang-il-an

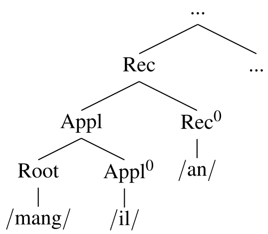


Table 5 shows the simple Reciprocal (a) and Applicative (b) structures, and the complex Applicativized Reciprocal (c) and Reciprocalized Applicative (d) structures. From this we can see that the simple Reciprocal is contained within the Applicativized Reciprocal, just as the simple Applicative is contained within the Reciprocalized Applicative. If we assume that morphosyntactic containment is what qualifies an output form for base-hood (Benua 1997:30, following Chomsky and Halle 1968, *et seq.*), then we correctly allow the Reciprocal to influence the Applicativized Reciprocal but not the Reciprocalized Applicative via Base-Derivative faithfulness.

The specific Base-Derivative (BD) faithfulness constraint that seems to be at work is CONTIGUITY (McCarthy and Prince 1995), defined in (37a), which requires that adjacency relations in the base are preserved in its derivative. Since the base of the Applicativized Reciprocal is the simple Reciprocal, where Reciprocal [an] is adjacent to the Root, CONTIGUITY will penalize candidate orders for the derivative where Reciprocal [an] is not adjacent to the Root, such as candidates (38a) and (38c). This BD-faithfulness constraint is counteracted by INTEGRITY (McCarthy and Prince 1995), defined in (37b), an Input-Output faithfulness constraint against splitting that will penalize any instance of suffix doubling. (We could also consider defining the relevant INTEGRITY constraint over the BD-correspondence relation.) In line with the earlier assumptions, INTEGRITY assigns violations for suffix doubling outputs, such as candidates (38c) and (38d), because we are interpreting them as instances of *phonological* splitting/copying.

(37) Faithfulness constraints

a. **CONTIGUITY-BD**: Assign one violation for each pair of segments which are adjacent in the base but not adjacent in the derivative.

b. **INTEGRITY-IO**: Assign one violation for each segment in the input with multiple correspondents in the output.

The way we derive the variation for the Applicativized Reciprocal is to have these two constraints stand in a variable ranking, below APPL-REC. If APPL-REC remains highest ranked, then it will continue to rule out (38b) and (38c). When a given derivation selects the ranking CONTIGUITY-BD ≫ INTEGRITY-IO (38.i), candidate (38.i.a)'s CONTIGUITY violation is fatal, and can only be repaired through doubling the /an/ suffix (38.i.d). When the derivation selects the opposite ranking (38.ii), it is now more important to avoid the INTEGRITY violation incurred by doubling (38.ii.d) than to remain faithful to the base, resulting in the CARP output (38.ii.a).

(38) Deriving the variation for the Applicativized Reciprocal

i. CONTIGUITY-BD ≫ INTEGRITY-IO → *doubling*

BASE: [mang-an-] ([[Root]Rec]) [[[Root]Rec]Appl] /mang$_{ROOT}$, il$_{APPL}$, an$_{REC}$/	APPL-REC	CONTIG-BD	INTEG-IO
a. mang-il-an- [AR]		*!	
b. mang-an-il- [RA]	*!		
c. mang-il-an-il- [ARA]	*!	*	**
d. ☞ mang-an-il-an- [RAR]			**

ii. INTEGRITY-IO ≫ CONTIGUITY-BD → *CARP*

BASE: [mang-an-] ([[Root]Rec]) [[[Root]Rec]Appl] /mang$_{ROOT}$, il$_{APPL}$, an$_{REC}$/	APPL-REC	INTEG-IO	CONTIG-BD
a. ☞ mang-il-an- [AR]			*
b. mang-an-il- [RA]	*!		
c. mang-il-an-il- [ARA]	*!	**	*
d. mang-an-il-an- [RAR]		*!*	

Understanding the variation in the Applicativized Reciprocal in this manner directly explains the lack of variation in the Reciprocalized Applicative. In the Reciprocalized Applicative, the base is the simple Applicative *mang-il-*. The doubling candidate that adheres to Base-Derivative CONTIGUITY in this case is the one that doubles Applicative /il/ (39c). But this candidate is ruled out by APPL-REC. The candidate that doubles the Reciprocal (39d) now actively violates CONTIGUITY-BD, rather than satisfying it as in the previous case. Since (39d) violates both CONTIGUITY-BD and INTEGRITY-IO, whereas candidate (39a) violates neither, (39a) will be selected as the unique winner regardless of which faithfulness ranking is selected.

(39) No variation for the Reciprocalized Applicative

BASE: [mang-il-] ([[Root]Appl]) [[[Root]Appl]Rec] /mang$_{ROOT}$, il$_{APPL}$, an$_{REC}$/	APPL-REC	CONTIG-BD	INTEG-IO
a. ☞ mang-il-an- [AR]			
b. mang-an-il- [RA]	*!	*	
c. mang-il-an-il- [ARA]	*!		**
d. mang-an-il-an- [RAR]		*!	*!*

This has demonstrated that appealing to BD-faithfulness accurately captures the variation (and lack thereof) seen in suffix doubling among Chichewa verbal extensions when integrated with the MAP + bigram constraints approach to linearization.[8] This BD-faithfulness approach might also help explain instances of the overapplication of palatalization in certain complex CARP forms in other Bantu languages discussed by Hyman (2003:Sect. 5); Myler (2017), and others. I leave this as an open question for future research.

3.5 Local conclusions

In this section, I have shown that the MAP can directly and restrictively capture the basic cases of MP-compliant mirror-image orderings in the Bantu languages as instantiated by Chichewa. Additionally, I have shown that the MAP framework is consistent with various approaches to asymmetric compositionality and the CARP template. Notably, it is flexible enough to integrate with approaches to templatic morphology located in different modules of the grammar, i.e., syntactic, morphological, or phonological.

I have focused on the phonological approach, where the MAP interacts transparently with bigram morphotactic constraints, following Ryan (2010). The MAP directly replaces Ryan's SCOPE constraint (Rice 2000), and thus allows us to maintain Ryan's restrictive ordering typology (see Table 3). Furthermore, I showed that this approach is compatible with an analysis of suffix doubling based in part on Base-Derivative faithfulness. If we accept this analysis, then it is clear that the MAP + bigram constraints interaction must truly be taking place in the phonology, because the analysis includes fine-grained phonological constraints like CONTIGUITY and INTEGRITY.

Before moving on, consider again that, in these analyses, the relative ranking of alignment constraints differs across different syntactic derivations; this is, in fact, the very nature of the proposal. This is somewhat unusual from the perspective of Optimality Theory, in which the constraint ranking is generally taken to be internally consistent within a language. But note that these are not purely phonological constraints; they crucially depend on morphosyntactic information, both with respect to their definitions and (by the MAP hypothesis) their rankings. This suggests that there may be principled ways in which the rankings of constraints that directly reference the morphosyntax can vary within a language.

This state of affairs bears some similarity to various phonological approaches to morpheme-specific phonology like Cophonology Theory (Orgun 1996; Inkelas 1998, 2014; Anttila 2002; Inkelas and Zoll 2005, 2007; Sande 2020; Sande et al. 2020; *a.o.*) and Indexed-Constraint Theory (Kraska-Szlenk 1997; Pater 2000, 2007, 2009; Becker 2009; Coetzee 2009; Nazarov 2019; *a.o.*), where, essentially, morpheme-specific constraint rankings are superimposed over a language-specific default ranking. However, in these theories, ranking differences across morphological constructions are arbitrary, and not limited to constraints that reference the morphosyntax or the morphology. Further comparison of the similarities and differences between the MAP and other such approaches may lead to a better understanding of the nature of ranking variation across derivations.

[8] Doubling also variably occurs in some constructions containing three CARP suffixes (Hyman and Mchombo 1992; Hyman 2003:272–275; Ryan 2010; Zukoff 2017b). I leave full accounting of these patterns for future work.

4 Arabic nonconcatenative morphology and the Mirror Alignment Principle

In Arabic, like many other Semitic languages, morphological word building frequently does not consist of sequential affixation to a fixed base of derivation.[9] Rather, these languages display nonconcatenative "root-and-pattern" morphological systems, where morphemes may be interspersed, and adding new morphemes often significantly alters the segmental order and/or larger prosodic organization of the word. (Consult, e.g., McCarthy 1979, 1981; Guerssel and Lowenstamm 1990 for overviews of the system and early generative analyses.) The Semitic root-and-pattern system has posed a persistent challenge to analysis at a number of levels.[10] One challenge has been how to understand this sort of system in light of the Mirror Principle. Because Baker conceived of word formation as a process of cyclic morphological concatenation (Baker 1985:378ff.), there was no clear way to reason about thoroughly nonconcatenative morphological processes/systems with respect to the MP in his framework (Baker 1985:400–403; LeTourneau 1997).

In this section, I develop a Mirror Alignment Principle analysis of several ordering alternations in Arabic. I show that these alternations are driven by differences in syntactic structure, based on a novel generalization tying the contrast between infixal and prefixal ordering to the structural height at which the morpheme adjoins to the Root. By inspecting the alignment rankings that generate the ordering differences, rather than inspecting the surface forms *per se*, we will find that Arabic's root-and-pattern morphology does in fact show exactly the sorts of MP effects discussed by Baker (1985), as instantiated by mirror-image ordering properties between Causative, Reflexive, and Root. Therefore, adopting the MAP's alignment-based approach to morpheme ordering and the (morpho)syntax-phonology interface newly brings nonconcatenative morphology under the umbrella of the MP. In Sect. 5, I will show how the MAP interacts with other phonological constraints to derive the detailed segmental ordering patterns in these and other Arabic verbal forms.

4.1 A MAP-based analysis of the reflexive

Arabic verbs are built around a consonantal root. The majority of roots consist of exactly three consonants, for example, /ktb/ 'write,' but roots consisting of two consonants and four consonants do also exist (see, e.g., McCarthy 1979 for further details). I limit my discussion here to canonical three-consonant roots.

The verbal system is divided into "Forms," built to these roots. Forms are morphosyntactic categories associated with a particular phonological shape (traditionally

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[9] "Arabic" here refers to Classical Arabic and Modern Standard Arabic. They do not differ significantly on the points under discussion, and I will thus draw on scholarship of both varieties.

[10] The following is a partial list of works which have sought to analyze the phonological properties—in concert with the morphosyntactic properties, in some cases—of Semitic nonconcatenative morphology: McCarthy (1979, 1981, 1993); Yip (1988); Guerssel and Lowenstamm (1990); McCarthy and Prince (1990a,b); Golston (1996); LeTourneau (1997); Gafos (1998, 2018); Ussishkin (2000a,b, 2003, 2005); Bat-El (2003, 2011); Lowenstamm (2005); Arbaoui (2010a,b); Tucker (2010, 2011); Wallace (2013); Faust (2015); Kastner (2016, 2019, 2020); Zukoff (2017a, 2021b); Kusmer (2019).

Table 6 Forms with Reflexive /t/ (for example root √*ktb* 'write'; data from McCarthy 1981:384)

Position	Form	Proposed morphosyntax	Example form	Translation
a. *Infixal*	VIII	Reflexive	***kt**ataba*	'write, be registered'
b. *Prefixal*	V	Reflexive of the Causative	***t**akattaba*	(*constructed form*)
	VI	Reflexive of the Applicative	***t**akaataba*	'write to each other'
	X	Causative of the Reflexive	*s**t**aktaba*	'write, make write'

described in terms of a CV "template") and a range of morphosemantics (often highly idiomatized). Within this system, Reflexive /t/ recurs across multiple Forms, sometimes as an *infix* (Table 6, (a)), sometimes as a *prefix* (Table 6, (b)).[11] The forms in Table 6 and throughout this section are given in the perfective active. Passive and imperfective forms will be incorporated into the analysis in Sect. 5. Note that the root √*ktb* does not attest a Form V form, so *takattaba* is not an actual word (McCarthy 1981:385fn.). A real Form V that rather transparently exemplifies the proposed semantics is *taħassana* 'improve, get better,' from the root √*ħsn* 'good,' whose basic verbal form is Form I *ħasuna* 'be good' (Ryding 2005:457, 530, 533).

This distribution cannot be due to phonotactics, as the alternative affixation patterns would yield phonotactically legal structures. Form VIII could have had a legal prefixal structure, such as ****t**aktaba* or ****t**akataba*. And Form V, for example, could have had a legal infixal structure, such as **ka**t**attaba* or **k**t**attaba*. Something beyond phonotactics is involved in determining this distribution.

Recent accounts (Tucker 2010, 2011; cf. Ussishkin 2003) have used alignment constraints to help derive the ordering alternation. However, an alignment-based analysis of the Reflexive requires an apparent ranking paradox, as shown in (40). That these paradoxical rankings properly derive the distribution is confirmed in (41).[12] In the candidate outputs, the Reflexive morpheme [t] is bolded and underlined, and the leftmost segment of the Root [k] is bolded.[13]

(40) Ranking paradox

a. Infixal Form (VIII): ALIGN-ROOT-L ≫ ALIGN-REFLEXIVE-L

b. Prefixal Forms (V,VI,X): ALIGN-REFLEXIVE-L ≫ ALIGN-ROOT-L

[11] I follow much of the literature, both descriptive (e.g. Fischer 2002:98) and theoretical (e.g. McCarthy 1981:389), in identifying this morpheme as Reflexive. However, this morpheme does not consistently produce argument structure alternations typical of reflexives (Itamar Kastner, p.c.), so it is not completely clear if this is the right designation. All that is important for the current argumentation is that the /t/ morpheme that shows up in multiple Forms is the exponent of the same morphosyntactic terminal (whatever that happens to be) and is in the hierarchical relations with Root that I claim it to be.

[12] Candidates where the Reflexive /t/ is immediately followed by the Root-initial /k/ are ruled out by a markedness constraint that is lexically-indexed to the Reflexive morpheme and several other verbal prefixes (Sect. 5.2). See Sect. 5 generally for explanation of additional phonological exigencies responsible for the non-minimal differences between the prefixal and infixal candidates, and consideration of additional candidates.

[13] Note that cluster-initial forms like Form VIII and Form X are repaired by preposed epenthesis of [ʔi] in phrase-initial position (i.e., phrase-initial clusters are not permitted, but word-initial clusters are). Epenthetic [ʔi] must be treated as being outside the domain of alignment, if present at this stage of evaluation at all. For this reason, I will omit them from word representations moving forward.

(41) Alignment-based derivation of the Reflexive alternation
(/t/ ⇔ REFL, /μ_c/ ⇔ CAUS, /a/ ⇔ PERF.ACT, /a/ ⇔ 3SG.MASC)

i. Infixal order: Form VIII Reflexive ***kt**ataba* [= (40a)]

/t, ktb, a, a/		ALIGN-ROOT-L	ALIGN-REFL-L
a.	**ta**k**t**aba	*!*	
b. ☞	**kt**ataba		*

ii. Prefixal order: Form V Reflexive of Causative ***tak**at$_c$taba* [= (40b)]

/t, μ_c, ktb, a, a/		ALIGN-REFL-L	ALIGN-ROOT-L
a. ☞	**tak**at$_c$taba		**
b.	**kt**at$_c$taba	*!	

Tucker (2010, 2011) circumvented this ranking paradox by indexing Form VIII to a special alignment constraint (basically: ALIGN-REFL$_{\text{VIII}}$-L ≫ ALIGN-ROOT-L ≫ ALIGN-REFL-L). This successfully avoids the problem, but does not provide explanatory power. However, armed with the MAP (repeated in (42)), there is a previously unnoticed syntactic generalization about this positional distribution of the Reflexive /t/, spelled out in (43), that can help deliver an explanation. (Slightly more will need to be said in order to explain Form X, the Causative of the Reflexive; see Sect. 4.3 below.)

(42) **The Mirror Alignment Principle** (repeated from (7) above)

a. If a terminal node α *asymmetrically c-commands* a terminal node β, then the alignment constraint referencing α *dominates* the alignment constraint referencing β.

b. *Shorthand*: If α c-commands β → ALIGN-α ≫ ALIGN-β

(43) Syntactic generalization about Reflexive /t/

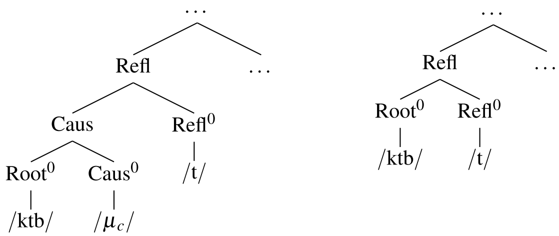
a. When Reflexive co-occurs with (and scopes over/c-commands) another verbal derivational morpheme (e.g. Causative or Applicative; cf. Table 8 and Table 9), its exponent is *prefixal*.

b. When Reflexive is the only verbal derivational morpheme, its exponent is *infixal*.

We can illustrate this difference by comparing the syntactic structures of Form V (the Reflexive of the Causative) and Form VIII (the simple Reflexive), as shown in (44).

(44) Syntactic structures with Reflexive

a. Form V ***tak**at$_c$taba* b. Form VIII ***kt**ataba*



Consider what the MAP has to say about the alignment rankings for these structures. In Form V (44a), Refl *asymmetrically c-commands* Root, since it adjoins to the complex head containing Root and Caus. The MAP thus produces the ranking Align-Refl-L ≫ Align-Root-L, which generates prefixal /t/ (41.ii).

In Form VIII (44b), on the other hand, Refl and Root stand in *symmetric c-command*, because Refl is the first head to adjoin with Root. Since the MAP only establishes rankings based on asymmetric c-command, the ranking between Align-Refl-L and Align-Root-L is underdetermined. (Importantly, this is also the case for the relative ranking of Align-Root-L and Align-Caus-L for Form V (44a).) These results are summarized in (45), where " , " indicates non-ranking.

(45) MAP-governed rankings with Reflexive

a. Form VIII (infixal order): Align-Root-L , Align-Reflexive-L
b. Form V (prefixal order): Align-Reflexive-L ≫ Align-Root-L

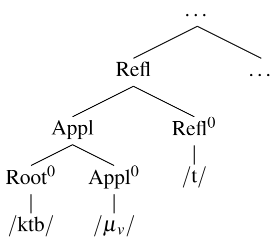
While we have now identified a distinction between the two types of structures' alignment behavior, the MAP itself doesn't explain why Reflexive /t/ is infixal in Form VIII. However, we can observe one further generalization:

(46) Root-alignment generalization
The (left edge of the) Root always surfaces further to the left than the first head which adjoins to it.

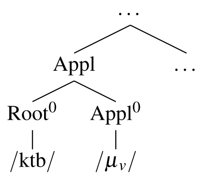
As mentioned above, this is the case not only for the relative positioning of Root and Reflexive in Form VIII ***kt̲**ataba* (44b), but also for Root and Causative in Form V *__tak__a__t̲__$_c$taba* (44a). This generalization holds also of the relative positioning of Root and Applicative in Form VI *__tak__a__a̲__$_v$taba* and Form III *__k__a__a̲__$_v$taba*, whose structures are provided in (47) below, and of Root and Causative in Form II (see Sect. 4.2).

(47) Syntactic structures with Applicative

a. Form VI *takaa$_v$taba*



b. Form III *kaa$_v$taba*



We can understand the generalization in (46) in terms of alignment. In each of the relevant cases, the constraint Align-Root-L outranks the left-oriented alignment constraint of the verbal derivational morpheme. Note crucially that these are exactly the cases where the MAP does not establish a ranking, because the two heads stand in symmetric c-command. If we assume that there is a language-specific default ranking (as previewed in Sect. 2.3) that emerges in the absence of contradictory instructions from the MAP, then we can account for all of these cases by positing the default ranking in (48):

(48) Language-specific default ranking for Arabic
Align-Root-L ≫ all the other alignment constraints

The existence of this sort of language-specific default ranking is something we'd expect in classical Optimality Theory (Prince and Smolensky [1993] 2004), where the phonological grammar simply contains a single constraint ranking. Insofar as the MAP approach involves derivation-specific re-ranking, the use of a default ranking may bear an even more striking resemblance to the concept of the "Master Ranking" in Cophonology Theory (Inkelas and Zoll 2007). In Inkelas and Zoll's view, the Master Ranking is the partial ranking of constraints which is consistent across a language's full set of cophonologies. Sande et al. (2020) take the Master Ranking to be a language-wide default, which may be overridden by, or (through cumulative constraint weighting) integrated with, morpheme-specific constraint rankings. I leave it to future work to further consider whether something like the "constraint resolution" mechanism in Sande et al. (2020:1223) could be used as a means of integrating MAP-prescribed rankings with a language-specific default (i.e. Master Ranking). It may also be fruitful to consider to what extent the relevant properties encoded by the "default ranking" may be universal, along the lines of the alignment relations discussed in Trommer (2001) and Kusmer (2019). For present purposes, it suffices to conclude that language-specific properties can be brought to bear to resolve ranking indeterminacy left over after the operation of the MAP.

Returning to the infixal Reflexive in Form VIII ***k**t̲**ataba* (44b), the default ranking in (48) steps in to resolve the indeterminacy (cf. (45)) in favor of ALIGN-ROOT-L. This now yields the ranking in (49a). The two distinct rankings in (49) are the paradoxical rankings from (40) above which generate the contrasting prefixal vs. infixal behavior of the Reflexive detailed in Table 6. Unlike in Tucker's (2010, 2011) constraint indexation approach, we have found an explanation for the apparent paradox: the dynamic interaction of the MAP and Arabic's default ranking as mediated by the syntactic structure.

(49) MAP-governed rankings supplemented by Arabic default ranking

a. Form VIII (infixal order): ALIGN-ROOT-L $\gg$ ALIGN-REFLEXIVE-L
b. Form V (prefixal order): ALIGN-REFLEXIVE-L $\gg$ ALIGN-ROOT-L

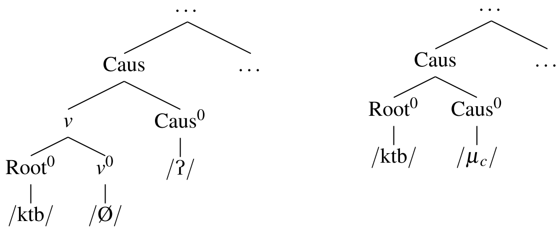
4.2 A MAP-based analysis of the causative

It is not only the Reflexive forms in Arabic that demonstrate this consistent interaction between the MAP and the language-specific default ranking in (48). So too do the forms involving Causative. Arabic has two basic types of morphological causatives (cf. Wright 1896:31–36; Ryding 2005:491, 515; Arbaoui 2010a,b; *a.o.*): Form II, which is marked by an infixal consonantal mora (/μ_C/), as in *ka**t**$_C$taba*; and Form IV, which is marked by a prefixal /ʔ/, as in ***ʔ**aktaba*.

The analysis of the Reflexive in the previous subsection gives us a roadmap for understanding this infix vs. prefix alternation. An infixal morpheme should be the first head to attach to the Root, such that the default high ranking of ALIGN-ROOT-L can emerge in the absence of a MAP-determined ranking. A prefixal morpheme should be a higher head, such that it asymmetrically c-commands Root, and the MAP can rank its alignment constraint above ALIGN-ROOT-L. If we reverse engineer the syntax in this way, we come up with the structures in (50). Note that we must posit a null *v* head in Form IV (50a) in order to create the necessary structures.

(50) Syntactic structures with Causative

a. Form IV *ʔaktaba* b. Form II *kat$_c$taba*



The phonological analysis based on the MAP thus predicts distinct syntactic structures for the two types of causatives. Does this supposed difference in syntactic structure correlate with other observable differences between the two Forms? The answer is *yes*: we can observe a difference in the semantics of the two categories.

Both Forms can contribute causative or factitive semantics (Wright 1896:31–36). Most Form IV forms have a canonically causative or factitive interpretation (Wright 1896:34). On the other hand, Form II forms have a substantially wider range of interpretations relating to causation or transitivity, such as (in Wright's parlance): intensive, extensive, iterative/frequentative, declarative, and estimative (Wright 1896:31–32).

The root √*ʕlm* 'know' provides a minimal pair that illustrates this distinction clearly (Wright 1896:34): it has a Form II causative *ʕa**l**$_c$lama* which means 'teach,' and it also has a Form IV causative ***ʔ**aʕlama*, which means 'inform' (≈ 'make someone know').[14] I have been able to identify four additional roots that attest both a Form II form and Form IV form, recorded in Table 7. While the last three roots in Table 7 do not transparently illustrate the difference, √*kbr* does seem to exhibit a similar distinction to √*ʕlm* with a more idiomatic reading in Form II *ka**b**$_c$bar-* 'extol' and a more transparent reading in Form IV ***ʔ**akbar-* 'deem great/important, magnify.'

Taking this distinction to be general, consider now the nature of the syntactic difference posited in (50). In Form IV, the Causative head selects a *v*P. In Form II, the Causative head directly selects the Root. Cross-linguistically, root-selecting heads allow more idiomatic semantics than non-root-selecting heads (Marantz 1997; Arad 2003; see also Kiparsky 1982, 1983, *et seq.* for similar ideas in the context of Lexical Phonology and Morphology). This is exactly what we observe in the semantics of these two Forms. The one which selects for Root (Form II) has a wide range of semantics, but the one which selects for *v*P (Form IV) has more consistent semantics.

We therefore have exactly the sort of correlation between ordering, syntactic structure, and semantics that we would expect in the MAP framework. Because the MAP generates morpheme order using a feed-forward modular architecture, syntactic differences should lead to ordering differences at PF the same way they lead to interpretative differences at LF. Furthermore, this section demonstrates that the MAP allows us to use phonological patterning to make falsifiable hypotheses about syntactic structure (and thus semantics), exactly as the MP envisions.

[14]Notably, this root also has a Form V *taʕallama* 'teach oneself, learn' (Fischer 2002:99), which transparently adds reflexive semantics to the Form II meaning. This matches well with the proposed syntactic structures, as the Form II structure (50b) is contained within the Form V structure (44a).

Table 7 Roots attesting both Causatives (perfective active stems)

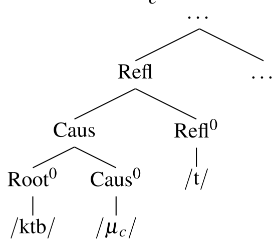
	√ʕlm		
Form I	*ʕalim-*	‘know’	(Ryding 2005:457; Fischer 2002:99)
Form II	*ʕallam-*	‘teach’	(Ryding 2005:515; Fischer 2002:99)
Form IV	*ʔaʕlam-*	‘inform’	(Ryding 2005:515)
	√kbr		[cf. *kabiir* ‘big, great’ (adj.); Ryding 2005:457]
Form I	*kabur-*	‘grow big, be big, grow older’	(Ryding 2005:457)
Form II	*kabbar-*	‘extol’	(Schramm 1962:361)
Form IV	*ʔakbar-*	‘deem great/important, magnify’	(Schramm 1962:362; Fischer 2002:100)
	√ktb		
Form I	*katab-*	‘write’	(Schramm 1962:360)
Form II	*kattab-*	‘cause to write’	(McCarthy 1981:374)
Form IV	*ʔaktab-*	‘dictate’	(Schramm 1962:361)
	√wqf		
Form I	not found		
Form II	*waqqaf-*	‘stop, halt’	(Ryding 2005:493, 515)
Form IV	*ʔawqaf-*	‘stop, halt’	(Ryding 2005:515, 517)
	√xbr		
Form I	*xabar-*	‘test, experience’	(Schramm 1962:361)
Form II	*xabbar-*	‘inform’	(Ryding 2005:515)
Form IV	*ʔaxbar-*	‘inform, notify’	(Ryding 2005:515; Schramm 1962:362)

4.3 Forms with reflexive and causative

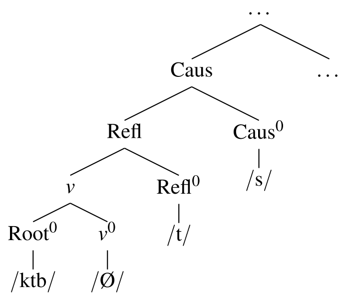
Before moving on, let us consider the Forms containing both Reflexive and Causative. We have already explained the Reflexive of the Causative (Form V), repeated in (51a). The Causative of the Reflexive (Form X), the last prefixal instantiation of Reflexive from Table 6, is given in (51b).

(51) Syntactic structures with Reflexive and Causative

a. Form V *takat$_c$taba*



b. Form X *staktaba*



To get both the Causative and Reflexive morphemes to be prefixal in Form X, we must again posit a null *v* head, the same head proposed for the Form IV causative. Form X frequently functions as the reflexive of Form IV (Wright 1896:44; Ryding 2005:584), so it should not be surprising that it contains the same null *v* head. For example, the root $\sqrt{}$*kbr* 'great' makes a Form IV causative *ʔakbar-* 'deem (s.t.) great/important,' and a Form X form *stakbar-* 'consider oneself great/important' (Schramm 1962:362; Fischer 2002:100), which serves as its Reflexive.

As has been evident, the phonological exponent of Causative varies across Forms: /μ_c/ in Forms II and V, /ʔ/ in Form IV, and /s/ in Form X. As a first approximation of what governs this allomorphy, we might appeal to a combination of structural conditioning and phonological conditioning, as follows. The /μ_c/ exponent appears in a specific morphosyntactic context, when Caus is sister to Root; the other exponents arise in the elsewhere context. The alternation between /ʔ/ and /s/ in the remaining forms is conditioned by phonological context: /ʔ/ before vowels, /s/ before consonants. There is comparative evidence indicating that the glottal stop /ʔ/ that expones Causative in Form IV derives historically from /s/ via sound change (Yushmanov 1961:49). This provides suggestive evidence in favor of unifying these two allomorphs against the other.

While this seems like a plausible explanation, it would lead to an inexorable circularity problem when paired with the phonological analysis to be proposed in Sect. 5 below, where the /ʔ/ morph (but not the /s/ morph) must be indexed to a constraint preventing it from surfacing in pre-consonantal position. Although a more insightful approach to the latter problem might resolve the circularity, I will at this point need to simply assert that these two allomorphs, just like the /μ_c/ allomorph, are distinguished on the basis of their morphosyntactic context. Each of the three allomorphs would thus be conditioned by a distinct specific context. Therefore, any combination of two allomorphs with their context specified will suffice to generate the correct distribution via Vocabulary Insertion.[15]

4.4 Interim summary

Nearly all of the structures and MAP rankings involved in the Form system have now been motivated. The one additional productive Form not yet mentioned is Form VII, which I will refer to as the Middle (Wright 1896:40–41). Its ordering properties are ultimately similar to those of Form IV, and thus I posit null *v* in Form VII as well, as shown in (52).

[15] Another odd fact about the /ʔ/ exponent is that it is absent on the surface in the Imperfective (see Table 10). While, e.g., McCarthy (1979:243–244) schematizes the Form IV Imperfective Passive as *yuʔaktabu*, the actual surface form is [yuktabu], with the /ʔ/ and the following vowel "missing." Citing Brame (1970:255), McCarthy assumes deletion by some mysterious later rule. Nevertheless, the [ʔ] in Form IV Perfectives cannot be (phrase-initial) epenthetic, because it is retained in post-consonantal position phrase-medially. How exactly to handle this whole complex of issues is an important question for future consideration.

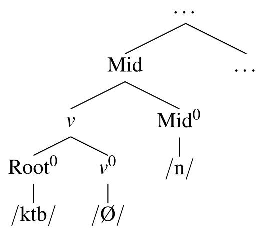
Table 8 Morphosyntactic structure and alignment analysis of verbal Forms

Form	Perf. Act.	Syntactic structure	Alignment Ranking		
I	*kataba*	[*v* [Root]]	ALIGN-ROOT-L	(≫ ALIGN-*v*-L)	
II	*ka**t**$_c$taba*	[Caus [Root]]	ALIGN-ROOT-L	≫ ALIGN-CAUS-L	
III	*ka**a**$_v$taba*	[Appl [Root]]	ALIGN-ROOT-L	≫ ALIGN-APPL-L	
IV	***ʔ**aktaba*	[Caus [*v* [Root]]]	ALIGN-CAUS-L	≫ ALIGN-ROOT-L	(≫ ALIGN-*v*-L)
V	***t**aka**t**$_c$taba*	[Refl [Caus [Root]]]	ALIGN-REFL-L	≫ ALIGN-ROOT-L	≫ ALIGN-CAUS-L
VI	***t**aka**a**$_v$taba*	[Refl [Appl [Root]]]	ALIGN-REFL-L	≫ ALIGN-ROOT-L	≫ ALIGN-APPL-L
VII	***n**kataba*	[Mid [*v* [Root]]]	ALIGN-MID-L	≫ ALIGN-ROOT-L	(≫ ALIGN-*v*-L)
VIII	*k**t**ataba*	[Refl [Root]]	ALIGN-ROOT-L	≫ ALIGN-REFL-L	
X	***st**aktaba*	[Caus [Refl [*v* [Root]]]]	ALIGN-CAUS-L	≫ ALIGN-REFL-L	≫ ALIGN-ROOT-L

Table 9 Morphemes involved in verbal Forms

Syntactic Heads		Morphs		Forms
Applicative		/μ_v/		III, VI
Reflexive		/t/		V, VI, VIII, X
Middle		/n/		VII
v		/Ø/		I, IV, VII, X
Causative	i.	/μ_c/	(sister to Root)	II, V
	ii.	/ʔ/	(sister to *v*)	IV
	iii.	/s/	(sister to Refl)	X

(52) Syntactic structure of the Middle Form VII ***n**kataba*



These structures and their associated MAP rankings are summarized in Table 8. Table 9 outlines the exponents of the relevant morphemes. With these components in place, I will now turn to a fuller phonological analysis of Arabic's root-and-pattern morphological system, which will explain not only the relative order of exponents, but the precise segmental ordering relations in the different Forms, spanning different Aspect and Voice paradigms.

5 MAP-based alignment and the morphophonology of the Arabic verb

In the previous section, I jointly motivated the syntactic structures and alignment properties of Arabic's Form system as mediated by the MAP. In this section, I will show how this morphosyntax-driven analysis interacts with Arabic's (morpho)phonological grammar to derive the precise segmental ordering patterns throughout the language's verbal paradigms defined by Aspect and Voice. Beyond the MAP-driven alignment constraints, the analysis will consist primarily of three parts: (i) a lexically-indexed phonotactic constraint motivating divergences from optimal alignment for certain affixes; (ii) constraints on vowel splitting that determine the number and positions of the vowels constituting the "vocalic melodies," i.e., the portmanteau exponents of Aspect and Voice; and (iii) the admission of "both-edge" alignment constraints into the Generalized Alignment schema, which will allow us to demonstrate that the alignment properties of the right edge mirror precisely the alignment properties of the left edge.

The takeaway from this analysis, in line with much of the recent literature (for example, the research program of "Generalized Nonlinear Affixation"; Bermúdez-Otero 2012; Bye and Svenonius 2012; Zimmermann 2017), is that nonconcatenative morphology is not fundamentally different from concatenative morphology from the perspective of the syntax and the morphology. Rather, nonconcatenative systems result from a language's general phonology—often displaying typologically unusual properties, such as Arabic's segregated consonant vs. vowel underlying representations—interacting transparently with the (morpho)syntax-phonology interface.

5.1 Data preview

The paradigms that will be the subject of this section are previewed in Table 10. In this table, the rows represent the different Form categories, with the Form affixes underlined. The columns represent the four combinations of values for Aspect (Perfective vs. Imperfective) and Voice (Active vs. Passive). Following relatively standard assumptions, I treat the exponent of Aspect and Voice as a portmanteau morpheme (henceforth abbreviated "AV") consisting of a sequence of vowels, as indicated by the underlying representations in the header row.[16] Peripheral subject agreement affixes are demarcated by morpheme boundaries (" - "). Agreement is suffixal in the perfect, but simultaneously consists of prefixal and suffixal exponents (i.e., circumfixes, at least descriptively) in the imperfective.

As is immediately evident, there are a number of similarities across various cells of these paradigms, but there are also surprising differences. Again, the goal of this section will be to explain why each segment in this table is in exactly the position it is in, and why there are unexpected differences between different cells of the paradigms.

5.2 Explaining the left edge

Let us begin with a problem with the high-level alignment analysis developed in Sect. 4, relating to the left edge of certain Forms. Take, for example, the Form V

[16] Arabic has only three vowels: /a,u,i/ (with long variants which may or may not be phonemic). We might thus expect some overlap between Aspect/Voice UR's even in the absence of shared exponents. Note also that the vocalic melody of Form I varies by root (e.g., McCarthy 1981:402–404; Guerssel and Lowenstamm 1990; Gafos 2018). This can probably be explained in terms of locality in allomorph selection given the absence of intervening heads in Form I. I leave the details for future study.

Table 10 Arabic verbal system (3SG.M of root $\sqrt{}$ktb 'write'; adapted from McCarthy 1981:385)

Form	Perf. Active /a/	Perf. Passive /ui/	Imperf. Active /???/	Imperf. Passive /ua/
I	katab-a	kutib-a	y-aktub-u	y-uktab-u
II	kat$_c$tab-a	kut$_c$tib-a	y-ukat$_c$tib-u	y-ukat$_c$tab-u
III	kaa$_v$tab-a	kuu$_v$tib-a	y-ukaa$_v$tib-u	y-ukaa$_v$tab-u
IV	ʔaktab-a	ʔuktib-a	y-u(ʔa)ktib-u	y-u(ʔa)ktab-u
V	takat$_c$tab-a	tukut$_c$tib-a	y-atakat$_c$tab-u	y-utakat$_c$tab-u
VI	takaa$_v$tab-a	tukuu$_v$tib-a	y-atakaa$_v$tab-u	y-utakaa$_v$tab-u
VII	nkatab-a	nkutib-a	y-ankatib-u	y-unkatab-u
VIII	ktatab-a	ktutib-a	y-aktatib-u	y-uktatab-u
X	staktab-a	stuktib-a	y-astaktib-u	y-ustaktab-u

perfective passive *tukut$_c$tiba* (53b). In the alignment analysis developed above, we posited the ranking ALIGN-REFLEXIVE-L ≫ ALIGN-ROOT-L in order to derive the correct relative order of Reflexive /t/ before Root-initial /k/. If this ranking is allowed to exert its influence unchecked, it predicts not (53b), where an AV vowel intervenes between [t] and [k] (hence two violations of ALIGN-ROOT-L), but (53a), a previously unconsidered candidate where [t] and [k] are stacked up at the left edge (with just one violation of ALIGN-ROOT-L). While the ranking ALIGN-AV-L ≫ ALIGN-ROOT-L could resolve this particular issue (since it prefers (53b) to (53a)), there is ample evidence, to be presented below, that we require the reverse ranking. Therefore, ALIGN-AV-L cannot be responsible for the disruption in alignment in these cases. (Note also that candidate (53b) splits AV /u/, incurring a violation of INTEGRITY not shared by (53a); see Sect. 5.3.)

(53) Form V perfective passive *tukut$_c$tiba* (alignment only) (cf. (41.ii))

/t$_{\text{REFL}}$, $\mu_{c\ \text{CAUS}}$, ktb, ui$_{\text{AV}}$, a$_{\text{AGR}}$/	ALIGN-REFL-L	ALIGN-ROOT-L	ALIGN-AV-L
a. 💣 tkut$_c$tiba		*	**
b. ☹ tukut$_c$tiba		**!	*
c. ktut$_c$tiba	*!		**

One way to explain this divergence from optimal alignment is to say that the Reflexive morpheme requires that it be followed by a vowel, or, equivalently, not be followed by a consonant. Under this view, there are three (sets of) morphemes that have this property: (i) Reflexive /t/ (evident in Forms V, VI, and X); (ii) Causative /ʔ/ (Form IV); and (iii) the left-edge agreement morphs found in the Imperfective (/y, t, ʔ, n/). In McCarthy (1979, 1981) and other templatic approaches, these are all morphemes/Forms which have to be associated to a template beginning in CV. Rather than building this into the representations, we can implement the generalization using a *lexically-indexed markedness constraint* (following Pater 2000, 2007, 2009; Flack 2007; *a.o.*), as defined in (54).

(54) ***AFX$_i$/_C**: Assign one violation for each morph(/segment) with the index *i* that precedes a consonant in the output.

{ *Alternatively*: AFX$_i$ | *CC (AFX$_i$ linked to the first C of *CC) or *C$_i$C }

As long as the morph(eme)s[17] just mentioned are indexed to this constraint, and it outranks the alignment constraints, we derive the desired outputs for these cases. This is demonstrated for Form V in (55). Exponents indexed to *AFX$_i$/_C are underlined in candidate outputs.

(55) Form V perfective passive *tukut$_c$tiba* (alignment plus *AFX$_i$/_C)

/t$_i$ REFL, μ_c CAUS, ktb, ui$_{AV}$, a$_{AGR}$/	*AFX$_i$/_C	ALN-REFL-L	ALN-RT-L	ALN-AV-L
a. tkut$_c$tiba	*!		*	**
b. ☞ tukut$_c$tiba			**	*
c. ktut$_c$tiba		*!		**

5.2.1 *AFX$_i$/_C and the Form system morphemes

The other Form system morpheme that is indexed to *AFX$_i$/_C is the Causative /ʔ/ found in Form IV. The constraint interaction works exactly the same as before, as shown in (56). In Forms without affixes indexed to *AFX$_i$/_C, such as Form VII with Middle /n/ (57), alignment can be maximally satisfied, allowing for clusters to surface at the left edge. Initial clustering is also found in Form VIII (reflexive). In this case, both alignment and *AFX$_i$/_C advocate for Reflexive /t/ to surface in pre-vocalic position (58a).

(56) Form IV perfective passive *ʔuktiba* (*AFX$_i$/_C active for /ʔ/)

/ʔ$_i$ CAUS, ktb, ui$_{AV}$, a$_{AGR}$/	*AFX$_i$/_C	ALN-CAUS-L	ALN-RT-L	ALN-AV-L
a. ʔkutiba	*!		*	**
b. ☞ ʔuktiba			**	*
c. kʔutiba		*!		**

(57) Form VII perfective active *nkataba* (*AFX$_i$/_C not active)

/n$_{MID}$, ktb, a$_{AV}$, a$_{AGR}$/	*AFX$_i$/_C	ALN-MID-L	ALN-RT-L	ALN-AV-L
a. ☞ nkataba	n/a		*	**
b. naktaba			**!	*
c. knataba		*!		**

(58) Form VIII perfective passive *ktutiba* (*AFX$_i$/_C active but superfluous)

/t$_i$ REFL, ktb, ui$_{AV}$, a$_{AGR}$/	*AFX$_i$/_C	ALN-RT-L	ALN-REFL-L	ALN-AV-L
a. ☞ ktutiba			*	**
b. kuttiba	*!		**	*
c. tkutiba	*!	*		**

Note that I represent a strict ranking between ALIGN-REFL-L and ALIGN-AV-L in (58). This is not necessary for the candidates considered, but it would be if we considered an additional candidate *[kututiba], with an extra [u]. This ranking does not follow from the MAP. For now, I will simply assume that it is part of the language-specific default ranking, which emerges because of a quirk of the post-syntactic structure. This will be explored further below.

[17] This constraint is indexed to the /ʔ/ exponent of CAUSATIVE, but not the /μ_c/ or /s/ exponents of CAUSATIVE. This indicates that the index is attached not to the "morpheme" (in the DM sense), but to the morph/exponent.

Table 11 Arabic verbal system (repeated from Table 10)

Form	Perf. Active /a/	Perf. Passive /ui/	Imperf. Active /???/	Imperf. Passive /ua/
I	katab-a	kutib-a	y-aktub-u	y-uktab-u
II	kat$_c$tab-a	kut$_c$tib-a	y-ukat$_c$tib-u	y-ukat$_c$tab-u
III	kaa$_v$tab-a	kuu$_v$tib-a	y-ukaa$_v$tib-u	y-ukaa$_v$tab-u
IV	ʔaktab-a	ʔuktib-a	y-u(ʔa)ktib-u	y-u(ʔa)ktab-u
V	takat$_c$tab-a	tukut$_c$tib-a	y-atakat$_c$tab-u	y-utakat$_c$tab-u
VI	takaa$_v$tab-a	tukuu$_v$tib-a	y-atakaa$_v$tab-u	y-utakaa$_v$tab-u
VII	nkatab-a	nkutib-a	y-ankatib-u	y-unkatab-u
VIII	ktatab-a	ktutib-a	y-aktatib-u	y-uktatab-u
X	staktab-a	stuktib-a	y-astaktib-u	y-ustaktab-u

5.2.2 *AFX$_i$/_C and imperfective agreement

As can be seen in Table 11, in the imperfective, a vowel always intervenes between the left-edge agreement morph and the next consonant, whether that consonant belongs to the Root or to a Form affix. This vowel varies by voice (and by Form, in the active), but not by person; i.e., the [ya] and [yu] of the 3rd person singular are matched by [ta]/[tu], [ʔa]/[ʔu], and [na]/[nu] in different person/number/gender configurations (see, e.g., Schramm 1962:364).

This strongly suggests that these vowels are *not* part of the agreement morpheme (cf. McCarthy 1981), but rather part of the AV morpheme (Brame 1970:70; Yip 1988:569). Therefore, just as with the Form system morphemes, we can derive the requirement of a second-position vowel by indexing the imperfective agreement morphs to *AFX$_i$/_C. For illustration, consider the Form I imperfective passive *yuktabu* (59), which follows from the same interaction that derived the more complex Forms above. I assume that the subject agreement node is the highest head in the verbal structure, allowing the MAP to rank ALIGN-AGR-L highest, resulting in alignment rankings like the one in (59).

(59) Form I imperfective passive *yuktabu* (*AFX$_i$/_C active for /y/)

/ktb, ua$_{AV}$, y$_i$(-)u$_{AGR}$/	*AFX$_i$/_C	ALN-AGR-L	ALN-RT-L	ALN-AV-L
a. ykutabu	*!		*	**
b. ☞ yuktabu			**	*
c. kyutabu		*!		**

5.3 Explaining the vocalic melodies

The interaction between alignment and *AFX$_i$/_C explains the behavior at the left edge of all the forms, both in the perfective and the imperfective. The largest remaining piece of the puzzle is the position and number of the Aspect/Voice vowels in the various Forms, which we can refer to as the "vocalic melody." My jumping off point is the (somewhat novel) generalizations in (60), which can be confirmed by the data in Table 11. (See McCarthy 1981:400; Yip 1988:565 for similar observations.)

(60) Phonological conditions on vowel splitting

a. No form has multiple instances of multiple distinct AV vowels (only one vowel splits).

b. Assuming the sonority scale $a \succ u \succ i$, whenever additional vowels are required in order to create well-formed structures, the most sonorous vowel splits.

These generalizations clearly hold in the Perfective Active, Perfective Passive, and Imperfective Passive, where the same combination of vowels in the same order appears across the different Forms. They hold also in the Imperfective Active, even though the set of vowels differs by Form.

Note that this cannot be recast in simple directional terms, as first pointed out by Yip (1988). In the Perfective Passive (/ui/) and Forms VII, VIII, and X in the Imperfective Active (/ai/), the *left-hand* vowel splits. But in the Imperfective Passive (/ua/), the *right-hand* vowel splits. This is problematic for directional autosegmental association accounts. For example, in order to maintain the *left-to-right* association convention, McCarthy (1981:401) had to stipulate a prior rule that associates /i/ to the right edge first.

We can use this phonological conditioning to generate the range of surface patterns from the compact underlying representations posited in Table 10/Table 11. I implement this with the faithfulness constraint INTEGRITY (McCarthy and Prince 1995), relativized to individual vowel qualities, ranked (inversely) according to their sonority value (61). I leave it as an open question why the ranking should be this way, that is, whether there is anything universal driving the ranking, or it is simply language-specific.

(61) Definition and ranking of INTEGRITY (sub-)constraints

a. *Definition of* **INTEGRITY[*x*]-IO**:
For each input segment of type *x*, assign one violation for each pair of corresponding output segments of type *x*.

b. *Ranking*:
INTEGRITY[i]-IO ≫ INTEGRITY[u]-IO ≫ INTEGRITY[a]-IO

This approach yields three desiderata: (i) it correctly selects *which* vowel splits when splitting occurs; (ii) it correctly predicts that only one underlying vowel is ever split in a given form; and (iii) it predicts that splitting will be minimal (subject to the needs of higher-ranked constraints), because more splitting incurs more violations. The primary drivers of INTEGRITY violation are *AFX$_i$/_C and the linear phonotactic constraint *CCC (62).

(62) ***CCC**: Assign a violation for each three-consonant sequence in the output.

One Form where splitting occurs is the Form X imperfective active *yastaktibu*, where there are *two* instances of [a] in the output. This form will demonstrate how the above constraints correctly derive the facts about the vocalic melodies.

5.3.1 Relative order via alignment

The relative order of consonantal morphemes is determined purely by the MAP-determined ranking of alignment constraints (cf. Table 8). This is illustrated in

(63). Word-initial four-consonant strings are not allowed—both because they violate *CCC and, in this case, they will incur violations of *AFX$_i$/_C—so, just as in previous cases, the perfectly aligned candidate (64a) will not be optimal.

(63) Ordering via alignment

ALIGN-AGR-L	≫	ALIGN-CAUS-L	≫	ALIGN-REFL-L	≫	ALIGN-ROOT-L
y	>	s	>	t	>	k

As long as INTEGRITY ranks *below* these alignment constraints, splitting AV vowels will always be better than reordering the consonantal morphemes as a repair for *AFX$_i$/_C. A candidate like **syaktitbu* (64c), which satisfies *AFX$_i$/_C by swapping the order of the exponents, excessively violates high-ranked alignment constraints (here, ALIGN-AGR-L and ALIGN-REFL-L). Therefore, the *relative* order will necessarily remain the one dictated by alignment, even if alignment violations must be tolerated in favor of (morpho)phonotactics. In the following tableaux, italicized vowels in the output are split vowels, incurring INTEGRITY violations.

(64) Form X imperfective active *yastaktibu*: ordering via alignment

/s$_{CAUS}$, t$_i$ $_{REFL}$, ktb, ai$_{AV}$, y$_i$(-)u$_{AGR}$/	*AFX$_i$/_C	ALIGN-AGR-L	INTEGRITY[a]
a. ystkatibu	*!*		
b. ☞ y*a*st*a*ktibu			*
c. syaktitbu		*!	

5.3.2 Splitting driven by *AFX$_i$/_C and *CCC

Holding the ordering of the consonantal morphemes constant, we can now see the full interaction between *AFX$_i$/_C, *CCC, and INTEGRITY. This is demonstrated in (65). As mentioned earlier, perfect alignment (65a) produces a long string of consonants at the beginning of the word, fatally violating both *AFX$_i$/_C and *CCC.

(65) Form X Imperfective Active *yastaktibu*: motivating splitting

/s$_{CAUS}$, t$_i$ $_{REFL}$, ktb, ai$_{AV}$, y$_i$(-)u$_{AGR}$/	*AFX$_i$/_C	*CCC	INTEGRITY[a]
a. ystkatibu	*!*	*!*	
b. ysatkitbu	*!*		
c. yastiktbu		*!	
d. ☞ y*a*st*a*ktibu			*

There is no way to fully repair both markedness problems by simply moving around the AV vowels without also splitting. Candidates (65b) and (65c) can each solve one problem, but no candidate can solve both simultaneously. Candidate (65b) places the two AV vowels after every second consonant from the left. This satisfies *CCC, but doesn't alleviate the *AFX$_i$/_C violations. Since (65d) is preferred to (65b), *AFX$_i$/_C must dominate INTEGRITY. Candidate (65c) places the two AV vowels after the two exponents indexed to *AFX$_i$/_C. This satisfies *AFX$_i$/_C, but creates a *CCC-violating cluster towards the right. Since (65d) is preferred to (65c), *CCC must dominate INTEGRITY. Only by splitting one of the vowels (65d) can both markedness constraints be satisfied simultaneously.

5.3.3 Splitting governed by INTEGRITY

Once splitting is motivated by *AFX$_i$/_C and *CCC, INTEGRITY does the rest, as shown in (66). INTEGRITY[i] ≫ INTEGRITY[a] ensures that underlying /a/ is split (66b) rather than underlying /i/ (66a). The ranking of the INTEGRITY constraints above other markedness constraints, e.g. NOCODA or *CC, ensures that additional splitting does not occur: (66b) ≻ (66c,d).[18]

(66) Form X Imperfective Active *yastaktibu*: governing splitting

/SCAUS, t$_i$ REFL, ktb, ai$_{AV}$, y$_i$(-)u$_{AGR}$/			INTEGRITY[i]	INTEGRITY[a]	NOCODA/*CC
a.		yast*i*kt*i*bu	*!		**
b.	☞	y*a*st*a*ktibu		*	**
c.		y*a*st*a*k*a*tibu		**!*	*
d.		y*a*s*a*t*a*k*a*tibu		**!****	

Note that candidate (66d) would actually be ruled out by alignment, because the extra [a] (the second one) intervenes between the left word-edge and the left edge of several left-oriented morphemes. Candidate (66c), though, does have the same alignment profile as (66b), because the extra vowel surfaces inside the root, interior to all the left edges.

5.4 Explaining the right edge

The last piece of the puzzle is explaining the relative positions of exponents towards the *right* edge of the stem. Nothing about the current analysis distinguishes, for example, the two candidate outputs for a Form X imperfective active in (67). In both forms, left-alignment of all the morphemes is maximized (subject to markedness and INTEGRITY), and there are the same number of codas and consonant clusters.

(67) Form X imperfective active

a. *yastak**ti**b-u* (stem-final VC)
b. **yastak**it**b-u* (stem-final CC)

The answer seems to lie in the longstanding generalization that all verbal stems (i.e. the material preceding the agreement suffixes) must *end in a VC sequence* (McCarthy 1979; McCarthy and Prince 1990b; *a.o.*). If something actively enforces this generalization, it will prefer *yastak**ti**b-u* (67a) over **yastak**it**b-u* (67b). The current alignment-based analysis presents a new explanation.[19]

5.4.1 Alignment and the right edge

Consider the following two facts. First, the stem-final VC sequence is always composed of the last AV vowel followed by the last Root consonant. Second, based on

[18] I have defined INTEGRITY to assign violations to all pairs of corresponding output segments, so the number of violations will increase exponentially as splitting increases. This has no effect on the evaluation as long as we are operating with constraint ranking rather than weighting.

[19] An alternative analysis based on McCarthy's (2005) "Optimal Paradigms" approach, which McCarthy shows can derive similar facts through paradigmatic overapplication, may be available. However, since that technology is not needed for the other facts examined here, I will not consider it further.

the behavior of the left edge of the stem, we know that ALIGN-ROOT ≫ ALIGN-AV. If these alignment constraints *also regulate the right edge*, then alignment derives the distribution. Furthermore, the right-side agreement morph always *follows* this VC sequence, just like the left-side agreement morph (in the imperfective) always *precedes* the Root and the AV morpheme at the left edge (cf. (59)). A right-oriented version of the alignment ranking that is independently needed for the left edge (68) generates the correct order in full (for agreement suffixes of any shape), as shown in (69) below.

(68) Right-oriented alignment ranking (to be refined):
ALIGN-AGR-R ≫ ALIGN-ROOT-R ≫ ALIGN-AV-R

(69) Form X imperfective active *yastaktibu*: explaining the right edge

/S_{CAUS}, $t_{i\ REFL}$, ktb, ai_{AV}, y_i(-)u_{AGR}/	ALN-AGR-R	ALN-RT-R	ALN-AV-R	INTEG
a. ☞ y*a*st*a*ktibu		*	**	*
b. y*a*st*a*kitbu		*	***!	*
c. yastikt*u*b*u*		*	***!**	*
d. yastiktub	*!		****	

Because ALIGN-AGR-R is highest ranked, agreement must be rightmost, ruling out (69d), which solves the markedness problems without splitting by moving the Agr /u/ inside the Root. This means there must be a violation of ALIGN-ROOT-R, and ensures the word-final sequence [bu]. Beyond that, the only constraint that cares which segment comes next is ALIGN-AV-R. This ensures that the rightmost AV vowel comes next (69a). Having the Root-medial /t/ surface next (69b) confers no benefit, nor does splitting the agreement affix and having it come next (69c); in fact, both worsen AV-alignment.

As long as ALIGN-AV-R dominates the INTEGRITY constraints, this approach also explains why agreement suffixes don't split even when they provide the most sonorous (and thus most splittable) vowel: doing so would worsen AV-alignment. We can see this in the Form V perfective passive 3SG.MASC (70), with AV morph /ui/ and agreement morph /a/. All candidates in (70) have the same CV shape, differing only in which vowel splits.

(70) Form V perfective passive *tukuttiba*

/$t_{i\ REFL}$, $\mu_{c\ CAUS}$, ktb, ui_{AV}, a_{AGR}/	ALIGN-AV-R	INTEG[i]	INTEG[u]	INTEG[a]
a. tukit$_c$t*a*b*a*	***!**			*
b. ☞ t*u*k*u*t$_c$tiba	**		*	
c. tuk*i*t$_c$t*i*ba	**	*!		

The ranking INTEG[i] ≫ INTEG[u] ≫ INTEG[a] prefers splitting the agreement morph /a/ (70a). But, this displaces the AV-final /i/ further left than the other splitting options, incurring extra ALIGN-AV-R violations. To ensure that the AV-final /i/ is as far to the right as possible, the AV-initial /u/ gets split instead (70b). Still, candidate (70b) is preferred to (70c) because it splits the more sonorous vowel without any consequences for alignment.

5.4.2 *Both-edge* alignment

We now see that we need both *left*-alignment and *right*-alignment for at least three distinct (classes of) morphemes: (i) the Root, (ii) the AV morpheme, and (iii) the (imperfective) agreement morphemes. This accounts not only for the ordering facts at the right edge, but also the (at least superficial) characterization of the imperfective agreement markers as circumfixes, i.e., morphemes that seek to align to both edges simultaneously.[20] This approach to some extent recapitulates Yip's (1988) notion of "Edge-In Association," which was largely motivated by the same facts.

I implement this by enriching Generalized Alignment (McCarthy and Prince 1993; Hyde 2012) as follows: a morpheme's alignment constraint can be specified as having *both edge* ("E") as its direction of alignment. *E*-alignment constraints are defined schematically in (71). We can understand this as a single alignment constraint that accumulates violations relative to both edges simultaneously. E-alignment thus forms a natural class with L[eft]-alignment and R[ight]-alignment, and should in principle be available to any type of morpheme in the same way that L- and R-alignment are available to any type of morpheme.

(71) **ALIGN-X-E:** Assign one violation for:

a. each segment which intervenes in the output between the *left* edge of the exponent of X and the *left* edge of the word, *and*

b. each segment which intervenes in the output between the *right* edge of the exponent of X and the *right* edge of the word.

As discussed above, in Arabic we need to identify E-alignment constraints for three classes of morphemes. One is ALIGN-ROOT-E, which encompasses the entire class of root morphemes. The second is ALIGN-AV-E, covering the four morphemes resulting from combination of [active/passive] and [perfective/imperfective]. The last is ALIGN-$\text{AGR}_{\text{IMPERFECTIVE}}$-E, applying to the imperfective agreement morphs, ranging across person, number, and gender categories.

Beyond the facts discussed above, one other place where we can see the effects of E-alignment is in the behavior of the perfective active AV morpheme /a/. If we assume a unisegmental underlying representation /a/ (rather than OCP-violating /aa/), we can view E-alignment as the driver of splitting in Form I, where one vowel would suffice for phonotactics (72). This holds equally well for consonant-initial agreement suffixes, such as the perfective 3PL.FEM /-na/ (73). For E-alignment constraints, violations for the left edge are indicated to the left of the " | "; violations for the right edge to its right.

(72) Form I perfective active 3SG.MASC *kataba*

/ktb, a_{AV}, a_{AGR}/	ALIGN-AV-E	INTEG[a]
a. katb-a	4! (*|***)	
b. ktab-a	4! (**|**)	
c. ☞ k*a*t*a*b-a	3 (*|**)	*

[20]Perfective agreement is aligned only to the right. Therefore, the direction of alignment must differ for the different agreement categories. Conceptually, we might relate this to the idea that the lexical index for *AFX_i/_C must apply to morphs not morphemes (see fn. 17). More thought about how this fits into the alignment system broadly is required.

(73) Form I perfective active 3PL.FEM *katabna*

/ktb, a_{AV}, na_{AGR}/	*CCC	ALIGN-ROOT-E	ALIGN-AV-E	INTEG[a]
a. katb-na	*!	2 (|**)	5 (*|****)	
b. ktab-na		2 (|**)	5! (**|***)	
c. ☞ k*a*t*a*b-na		2 (|**)	4 (*|***)	*
d. k*a*tb*a*-na		3! (|***)	3 (*|**)	*

There is an outstanding problem regarding a candidate like *[k*a*t-n-*a*b-a], where the Root and the AV morph intrude into the multisegmental agreement suffix /-na/. The obvious answer would be to introduce a high-ranked CONTIGUITY$_{AFFIX}$ faithfulness constraint that advocates for maintaining underlying adjacency relations within affixal exponents. However, this will require further scrutiny about the representation of the imperfective agreement morphemes, which are definitionally discontiguous, and the AV morphemes, which always surface discontiguously. This may motivate lexically-indexing CONTIGUITY to certain morphemes, in parallel to the lexically-indexed markedness constraint *AFX$_i$/_C.

5.5 The MAP and the ranking of ALIGN-AV

Throughout this section, I have consistently represented ALIGN-AV-E as being low ranked. In various instances, this low ranking is crucial. One such case is the interaction between ALIGN-AV-E and ALIGN-ROOT-E in the Form I perfective passive (74). Tableau (75) shows an additional case where this ranking is crucial, the Form VII perfective active. In this form, the optimal output is clearly not otherwise phonotactically optimizing. This ensures that it is indeed alignment that is driving the derivation, not markedness considerations.

(74) Form I perfective passive *kutiba*

/ktb, ui_{AV}, a_{AGR}/	ALIGN-AGR$_{PERF}$-R	ALIGN-ROOT-E	ALIGN-AV-E
a. ☞ kutiba		1 (|*)	3 (*|**)
b. uktiba		2! (*|*)	2 (|**)
c. ukitab	*!	1 (|*)	3 (|***)

(75) Form VII perfective active *nkataba*

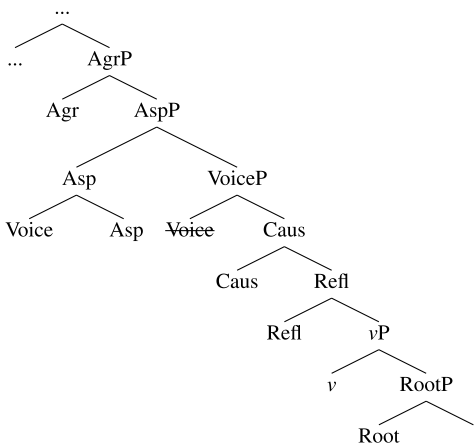
/n_{MID}, ktb, a_{AV}, a_{AGR}/	ALIGN-MID-L	ALIGN-ROOT-E	ALIGN-AV-E
a. ☞ nkataba		2 (*|*)	4 (**|**)
b. naktaba		3! (**|*)	3 (*|**)
c. knataba	*!	1 (|*)	4 (**|**)
d. ankataba	*!	3 (**|*)	2 (|**)

The fact that ALIGN-ROOT-E must outrank ALIGN-AV-E should give us pause when we think about it in terms of the MAP. Standard assumptions about the clausal spine (see, e.g., Cinque 1999) would locate the Aspect and Voice heads substantially higher than the Root. We should therefore expect that Aspect and Voice would asymmetrically c-command Root, and thus Aspect/Voice's alignment constraint should be ranked higher than Root's by virtue of the MAP. But this is exactly the opposite of the ranking we observe in the phonology.

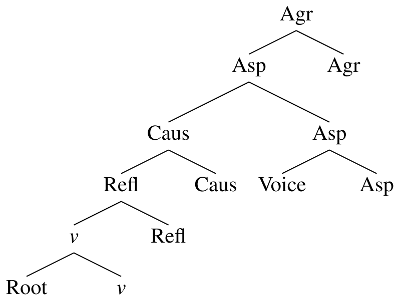
While a full accounting must be postponed for reasons of space, I would like to suggest that we can square this circle by positing a (post)syntactic operation that has the effect of disrupting the expected c-command relations. Notice that Aspect and

Voice are consistently exponed together as a portmanteau. This sort of fact ought to be captured through the application of syntactic and/or morphological processes of the language, rather than through accidents of Vocabulary Insertion. Put another way, the consistent portmanteau exponence implies that there is something special about the structural relationship between Aspect and Voice. One possibility is that some operation, whether in the narrow syntax or in the post-syntax, raises Voice to Aspect (76) *prior* to roll-up head movement (77).[21]

(76) Syntactic structure of Form X after Voice-to-Asp movement



(77) Form X complex head after roll-up head movement



According to the version of c-command employed for the MAP in this paper (i.e., using only the lowest segment of each terminal node), based on the structure in (77), Asp and Voice do not asymmetrically c-command any other head. Therefore, the MAP will not assert a crucial ranking between their alignment constraint(s) and any other alignment constraints. This allows the language-specific default ranking, where ALIGN-ROOT is the highest ranked alignment constraint (see (48)), to kick in and fix the ranking of ALIGN-ROOT-E over ALIGN-AV-E for all derivations.[22]

[21] Zukoff (2021a) proposes a similar analysis that derives the equivalent structure using Harizanov and Gribanova's (2019) "amalgamation" operation.

[22] That on its own might not be sufficient, however, to explain the few cases like the Form VIII perfective passive *ktutiba*, shown in (i) below (cf. (58)), where ALIGN-AV-E must rank even lower, be-

With respect to (77), we do additionally want to posit some sort of merger operation to combine Asp and Voice into a single head containing the features of both, such that we can derive the portmanteau exponence via Vocabulary Insertion into that single head position. This is the only configuration of heads within the verb word (other than Root and the first head it attaches to) where the lowest segments stand in symmetric c-command. If this configuration uniquely induces some sort of *fusion* operation (Halle and Marantz 1993) that fuses the lowest segments into a single feature bundle, then the traditional approach to Vocabulary Insertion within DM, with insertion into terminal nodes governed by the subset principle (Halle 1990, 1997; Halle and Marantz 1993, *et seq.*), would generate consistent portmanteau exponence of Aspect and Voice. Crucially, though, this fusion operation must leave the intermediate segment of Asp intact, or else the fused head would regain its asymmetric c-command over the lower heads. This rules out similar operations like M-Merger (Matushansky 2006) or Coalescence (Hsu 2021).

This analysis may make an interesting prediction about portmanteau morphemes cross-linguistically.[23] We predict that the alignment of portmanteau morphemes derived in this way—i.e., movement followed by roll-up head movement followed by fusion—should not be (fully) subject to the MAP (or indeed to the MP more generally), because they lack the kinds of c-command relations typically found within complex heads. Rather, their ordering should instead be based on language-specific default rankings or other such (potentially universal) principles (Trommer 2001). On the other hand, apparent portmanteau morphemes that are actually the result of contextual allomorphy, or exponents inserted through spanning (Svenonius 2012; Merchant 2015), *would* be expected to participate in the MAP in the normal way. I leave investigation of this prediction for future work.

5.6 Analysis summary

This section has offered a detailed (morpho)phonological account of Arabic's root-and-pattern verbal system. The central component of this analysis is the ranking of alignment constraints, as determined by the interaction between the MAP and the language's default alignment ranking. As summarized in (78) below, these alignment constraints consistently rank below the two markedness constraints operative in the analysis, *AFX$_i$/_C and *CCC, and above the INTEGRITY constraints. Given this

low ALIGN-REFL-L. This may motivate supplementing the default ranking to include the low ranking of ALIGN-AV-E, as shown in (ii) below.

(i) Form VIII perfective passive *ktutiba* (cf. (58))

<table>
<tr><th>/t$_i$ REFL, ktb, ui$_{AV}$, a$_{AGR}$/</th><th>*AFX$_i$/_C</th><th>ALN-RT-E</th><th>ALN-REFL-L</th><th>ALN-AV-E</th></tr>
<tr><td>a. ☞ kṯutiba</td><td></td><td>1 (|*)</td><td>*</td><td>4 (**|**)</td></tr>
<tr><td>b. k*u*ṯ*u*tiba</td><td></td><td>1 (|*)</td><td>**!</td><td>3 (*|**)</td></tr>
<tr><td>c. kuṯtiba</td><td>*!</td><td>1 (|*)</td><td>**</td><td>3 (*|**)</td></tr>
<tr><td>d. ṯkutiba</td><td>*!</td><td>2 (*|*)</td><td></td><td>4 (**|**)</td></tr>
</table>

(ii) Language-specific default ranking for Arabic (updated) (cf. (48))
ALIGN-ROOT-E ≫ all the other alignment constraints ≫ ALIGN-AV-E

[23] Thank you to Ezer Rasin for pointing this out to me.

Table 12 Morphosyntactic structure and alignment analysis of verbal Forms

Form	Perf. Act.	Syntactic structure	Alignment Ranking		
I	*kataba*	[*v* [Root]]	Align-Root-E	(≫ Align-*v*-L)	
II	*ka**t**$_C$taba*	[Caus [Root]]	Align-Root-E	≫ Align-Caus-L	
III	*ka**a**$_V$taba*	[Appl [Root]]	Align-Root-E	≫ Align-Appl-L	
IV	***ʔ**aktaba*	[Caus [*v* [Root]]]	Align-Caus-L	≫ Align-Root-E	(≫ Align-*v*-L)
V	***t**aka**t**$_C$taba*	[Refl [Caus [Root]]]	Align-Refl-L	≫ Align-Root-E	≫ Align-Caus-L
VI	***t**aka**a**$_V$taba*	[Refl [Appl [Root]]]	Align-Refl-L	≫ Align-Root-E	≫ Align-Appl-L
VII	***n**kataba*	[Mid [*v* [Root]]]	Align-Mid-L	≫ Align-Root-E	(≫ Align-*v*-L)
VIII	*k**t**ataba*	[Refl [Root]]	Align-Root-E	≫ Align-Refl-L	
X	***st**aktaba*	[Caus [Refl [*v* [Root]]]]	Align-Caus-L	≫ Align-Refl-L	≫ Align-Root-E

simple characterization of the interaction between the alignment constraints and the more traditional phonological constraints, it is clear that the majority of the work is indeed being done by the alignment constraints, which are the avatars of the morphosyntax in the phonology.

(78) Ranking summary of Arabic morphophonological analysis

$*\text{Afx}_i/\_C$ *CCC

The set of ALIGNMENT CONSTRAINTS, differently ranked per derivation

Integrity[i]

Integrity[u]

Integrity[a]

NoCoda/*CC

The morphosyntactic structures for each Form are repeated in Table 12. This table is identical to Table 8, except that the Root's alignment constraint now correctly reads Align-Root-E to indicate that it is a both-edge alignment constraint. The ranking fragments in Table 12 each need to be supplemented with two constraints to complete any given derivation. The first is the alignment constraint for the agreement morpheme, either $\text{Align-Agr}_{\text{PERFECTIVE}}$-R or $\text{Align-Agr}_{\text{IMPERFECTIVE}}$-E, depending on Aspect. This constraint is consistently ranked *above* the constraints in Table 12 by the MAP, because it is the highest head in the verb word. The second is the alignment constraint for Aspect and Voice, Align-AV-E, the other both-edge alignment constraint. Because of the pre-head-movement operation that breaks Aspect and Voice's c-command relations, the language-specific default ranking causes this constraint to fall to the bottom of the ranking in all derivations. Therefore, Align-AV-E ranks *below* all the fragments in Table 12. Plugging these alignment rankings into the total ranking in (78) correctly derives the phonological output form for every syntactic input discussed in Sects. 4 and 5.

5.7 Local conclusions

The MAP approach offers new insights about the relationship between the verbal (morpho)syntax of Arabic and its (morpho)phonological system, and provides a more complete and consistent account of its phonological complexities and typological unusualness. Adopting the MAP approach also brings nonconcatenative morphological processes under the umbrella of phenomena which illustrate the Mirror Principle:

(79) The Mirror Principle (Baker 1985:375)
Morphological derivations must directly reflect syntactic derivations (and vice versa).

By using *alignment rankings* determined via phonological analysis, rather than just linear order, to infer the underlying word-internal structure, we can apply MP reasoning to infer syntactic structure from surface morpheme order for any sort of morphological system, concatenative or otherwise.

6 Discussion and conclusion

This paper has introduced and developed a new proposal regarding the nature of morpheme ordering, based on the operation of the Mirror Alignment Principle (MAP) at the morphology-phonology interface. The MAP is an algorithm that translates hierarchical structural relations (asymmetric c-command) between morphosyntactic terminals into ranking relations between alignment constraints on the exponents of those morphosyntactic terminals in the phonological component. This algorithm provides a principled means of capturing "Mirror Principle" (MP) effects (Baker 1985, 1988a), whereby the order of morphemes in a complex word mirrors the order of syntactic derivation and hierarchical morphosyntactic structure.

The MAP approach eschews the more traditional cyclic morphological concatenation approach to morpheme ordering and the MP, instead determining the linear order of morphemes by concatenating their phonological exponents through simultaneous global evaluation in the phonology. Dispensing with morphological concatenation allows for the possibility of bringing nonconcatenative morphological processes back into the fold of MP-related phenomena. As demonstrated in Sect. 4, linking the relative ranking of alignment constraints in individual derivations to correlated differences in syntactic structure allows for a principled explanation of what would otherwise constitute a ranking paradox in Arabic's nonconcatenative morphological system. The alignment rankings that are necessary for the phonological analysis, when guided by the MAP, point to morphosyntactic representations which look completely sensible from a cross-linguistic perspective, and may even reveal mirror-image ordering properties similar to those seen in Bantu in Sect. 3.

The MAP framework indeed straightforwardly captures the sorts of mirror-image morpheme orderings seen in Chichewa and other Bantu languages. Differences in syntactic structure map directly onto differences in alignment rankings, which generate different surface orders. These mirror-image ordering properties are embedded within a larger, more complex system of asymmetric compositionality and fixed ordering, collectively referred to as the "CARP template" (Hyman 2003). While I have not tried to adjudicate between different possible analyses of the CARP template, this paper has shown that the MAP is flexible enough to join with many different kinds of approaches to the problem, located in various modules of the grammar. One specific analytical finding is that Ryan's (2010) bigram morphotactic constraint approach can be combined with the MAP and Base-Derivative faithfulness (Benua 1997) to account for certain patterns of suffix doubling in the phonology.

Additionally, the use of alignment constraints in the implementation of morpheme ordering furnishes another desideratum. First, morphological concatenation algorithms (such as the one proposed by Embick 2007, 2015) have no built-in means of resolving the linear indeterminacy between concatenated elements. That is to say, a morphosyntactic structure [x[yz]] could be linearized as *x*-[*y*-*z*], *x*-[*z*-*y*], [*y*-*z*]-*x*, or [*z*-*y*]-*x*, and still obey the concatenation algorithm (and thus the MP), which itself has no left/right ordering instructions. By implementing the entire procedure using alignment constraints, we avail ourselves of the inherent directionality of Generalized Alignment (McCarthy and Prince 1993; Hyde 2012): the possible orders are weeded out according to the language particular choice of alignment direction for a particular (class of) morpheme.

This is not to say that there aren't other principles involved in determining the direction of alignment for individual (classes of) morphemes. For example, Trommer (2001) uses typological ordering facts to assert universal preferences for the direction of alignment of different kinds of agreement morphemes/features. None are exceptionless, so it is not certain that this should universally limit possible directionality in individual languages. Yet, if agreement nodes are typically "sprouted" in the post-syntax (e.g. Halle and Marantz 1993; Embick 2000; Choi and Harley 2019), then they may frequently end up in a similar configuration to that of Arabic Aspect/Voice (Sect. 5), and thereby be exempted from full participation in the MAP. In a different vein, Kusmer (2019) introduces constraints relating to "antisymmetry" and "head-finality," concepts familiar from syntactic linearization (Kayne 1994), into word-level morphophonological computations. While his system is not directly compatible with the MAP, it may be possible to leverage these concepts in explaining the direction of alignment in certain instances.

While this paper has limited the application of the MAP to word-level phenomena, the MAP is in principle capable of contributing to the ordering properties of higher-level constituents, as well. The syntactic structure obviously furnishes phrases in addition to heads, and the prosody/phonology furnishes constituents above the level of the word. Generalized Alignment, implemented in various ways, has long been appealed to in this domain (e.g. Truckenbrodt 1995; Selkirk 2009; among many others) to relate constituents of the respective types. The MAP could play a part in determining the ranking of alignment constraints for different constituents according to the hierarchical structure of the phrase/sentence-level syntax, as opposed to just complex heads. These alignment-based ordering properties might assert themselves only in cases of indeterminacy in syntactic linearization (cf. Kayne 1994), or perhaps they could play an even more central role in syntactic linearization itself. Therefore, the Mirror Alignment Principle provides a number of directions for future investigation across multiple domains of the (morpho)syntax-phonology interface.

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