ABSTRACT

Title of Dissertation: PRECEDENCE AND THE LACK THEREOF: PRECEDENCE-RELATION-ORIENTED PHONOLOGY

Maxime Papillon, Doctor of Philosophy, 2020

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The study of representations, their limits and capacities, is an indispensable part of the formal study of language. The representations are the limits of what can be stored and computed upon, and the details of a representation have a major influence on the form of any analysis. Broadly, the goal of this thesis is to explore a lower bound of complexity for the phonological module. By exploring the capacities of a representation that I will argue requires fewer stipulations than anything offered before it, I will defend the claim that the freedom of this more powerful representation matches the power of morphology. More specifically I will argue that the representation of phonology is not strings, but directed graphs, and that this representation is simpler and more powerful and that its power exactly matches the set of attested phenomena of word-formation and phonology. The goal of this dissertation is to expand on the theory of Multiprecedence (Raimy, 2000), which is both promising and under-explored.

PRECEDENCE AND THE LACK THEREOF: PRECEDENCE-RELATION-ORIENTED PHONOLOGY

by

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Chapter 1

Introduction

> Wherever we go we are impressed by the fact that pattern is one thing, the utilization of pattern quite another... we cannot but conclude that linguistic form may and should be studied as types of patterning, apart from the associated functions. Sapir, 1921, p.61-62

The study of representations, their limits and capacities, is an indispensable part of the formal study of language. The representations are the limits of what can be stored and computed upon, and the details of a representation have a major influence on the form of any analysis.

Broadly, the goal of this thesis is to explore a lower bound of complexity for the phonological module. By exploring the capacities of a representation that I will argue requires fewer stipulations than anything offered before it, I will defend the claim that the freedom of this more powerful representation matches the power of morphology.

More specifically I will argue that the representation of phonology is not strings, but directed graphs, and that this representation is simpler and more powerful and that its power exactly matches the set of attested phenomena of word-formation and phonology.

The ideas described in this thesis are most obviously a development of the ideas expressed in Raimy (1999, 2000) in that it explores the full extent of the representational power of directed graphs in phonology, as the main data structure needed. This thesis also pursues more generally the program we could call 'nonlinear generative phonology' after the title of Clements (1980) in drawing from the insights of autosegmental phonology, especially as it pertains to moving away from strings as a data structure and taking features to have an amount of independence from each others, forming independent autosegments.

I also see this work as pushing the limits of underspecification theory, broadly the view that the phonology operates on forms which, underlyingly and in the course of computation,

contain less information than a strict description of the surface pronunciation (Clements 1988 and Archangeli 1988, among many others). But beyond underspecification at the level of the content of segments, I propose underspecification of the very linear order of segments, such that, underlyingly and in the course of the computation, the linear order of two or more segments may be undetermined. PROP takes precedence to be phonological information, and as such this can be seen as pushing Archangeli's stated goal that 'underspecification theory applies to all phonological information, not simply to feature values' (p.12) even further than she did. Furthermore, paralleling the advances of underspecification theory such as Keating (1988) who pursued the idea of underspecification all the way into the phonetics, resolved by general principles of motor planning, I similarly attribute some resolution of underspecified ordering to downstream planning and articulatory compatibility as we will see through out the thesis.

Empirically, most of what is discussed in this thesis belongs to what could broadly be termed 'non-canonical phonology': tone, vowel harmony, reduplication, allomorphy. These phenomena have long been at the forefront of debates over the fundamentals of phonology and morphology. It is crucial to explore the most powerful phenomena of the world's languages to truly appreciate the capacities of Phonology as a unified system. I am not the first of course. Hyman (2018), for instance, claims that tone is important for phonology, using the slogan-like claim that 'Tone is like segmental phonology in every way–only more so' and, expanding on a similar claim from Hyman (2011), notes that:

> anyone who is interested in the outer limits of what is possible in phonology and morphology would thus be well-served to understand how tone systems work

Reduplication has also played a central role in phonological theory in the last few decades as a domain where the most complex phonological data enriched the theory.

This dissertation is intended to be of cross-linguistic coverage. The discussion of the many phenomena involved will lead us to discuss at least briefly some patterns from many dozen languages.

Chapter 2 is a brief recapitulation and expansion of the original theory of Raimy (2000) from which I depart. Raimy's theory was only intended to account for reduplication and

other affix types like prefixes, suffixes and infixes. I will from now on refer to this theory as it is described in Raimy (2000) and subsequent papers as Multiprecedence and I will distinguish it from Precedence-Relation Oriented Phonology (PROP) which is the radical extention from it I will argue for in this dissertation.

Chapter 3 tackles together two immense topics: vowel harmony and word-tone phenomena. With a simple assumption I will show that the basic structure of Multiprecedence can be readily expanded to account for these phenomena in a fundamental way that naturally derives from the representation.

In chapter 4 I will discuss the positioning of affixes and how they can also benefit from PROP analyses. This chapter is importantly a jumping off point to the following chapters.

In chapter 5 I discuss Phonologically-Conditioned Allomorphy. A simple representational possiblity allows for multiple interesting types of PCA to be handled in a completely novel way within the phonology. This radically novel way to handle suppletion has multiple empirical and conceptual advantages when it comes to coverage and to the design of the linguistic system, which will be discussed in this chapter.

Chapter 6 extends the ideas of chapter 5 to Morphologically-conditioned Allomorphy by incorporating some ideas from chapter 4.

Chapter 7 incorporates the insights of the previous chapters and explore their interaction with reduplication so as to fully incorporate PROP as a continuation of Raimy's Multiprecedence.

Chapter 8 is a promisory note on the theory of PROP, taking the assumptions and claims made in the previous chapters and relates them to what they imply about phonetics, acquisition, and psycholinguistics.

And finally chapter 9 is a cursory discussion of ideas that remain to be explored in detail within the world of PROP on top of the main ones of the previous chapters, including the inclusion of regular phonological processes into PROP and how some of them may be replaced or illuminated by PROP principles, a discussion of complex segments, of the morphology of ineffable forms, other word-formation phenomena that did not fit into previous chapters, as well as what PROP could do for the phonology of structures above the word-level.

The discussion to come is at times recapitulative of things other theories do well and at other times wildly speculative. The goal of this dissertation is to expand on a theory that is both promising and under-explored.

Chapter 2

Preliminaries: Raimy (2000), strings and precedence

This chapter will introduce the theory of Precedence-Relation-Oriented Phonology (PROP). Because it derives mostly from the Multiprecedence representation used in Raimy (1999, 2000), section 2.1 will summarize the theory of Multiprecedence and section 2.2 will distill the parts of Multiprecedence that will be used in the rest of this dissertation.

2.1 Raimy 2000

The basic point of departure from standard phonology that Raimy took was to ask was what could happen if instead of using the string as our basic representation we used a structure with fewer stipulations: sets of pairs of segments in a precedence relation from the first to the second, bounded by a START point and and END point. He used this structure to derive morphophonological phenomena in a novel way that allowed him to account in a derivational theory for difficult phenomena in the interaction of regular phonology with reduplication and infixation. This section will cover the mechanics and some of the empirical facts that this representation could derive elegantly, and it will summarize some of the directions that have been explored by others working in Multiprecedence Phonology.

2.1.0.1 Precedence relations

Consider a string like (1-a), the familiar way to think of what phonology operates over. An alternative way to encode that same information is in the form of a set of precedence statements like (1-b). For legibility the set of pairs in (1-b) can be represented in the form of a graph diagram; adding the convention that of using # and % for the START and END symbols respectively we get the picture in (1-c). In general I will refer to this view as the

graph representation.

(1) a. kæt

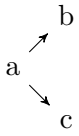
b. $\{\langle START, k\rangle, \langle k, æ\rangle, \langle æ, t\rangle, \langle t, END\rangle\}$

c. $\# \rightarrow k \rightarrow æ \rightarrow t \rightarrow \%$

The main difference between such a representation and a string-based one is that since the precedence pairs are all there is, there is no restriction as to what the set of them can be. For instance segments can be in precedence relations with multiple other segments as in (2), two segments can be in a precedence relation with each other as in (3), and segments can precede themselves as in (4).

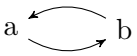
(2) a. $\{\langle a, b\rangle, \langle a, c\rangle\}$

b.



(3) a. $\{\langle a, b\rangle, \langle b, a\rangle\}$

b.



(4) a. $\{\langle a, a\rangle\}$

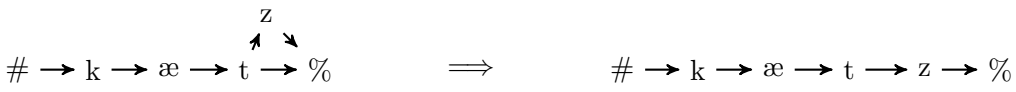
b.

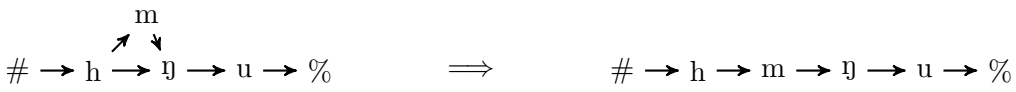
In Raimy's system the geometrical possibilities of the representation end up carrying weight in describing the interaction of morphology and phonology. The goal of this paper

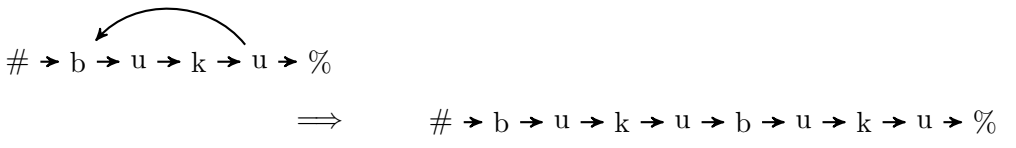
is to show that the geometrical possibilities of multiprecendence go beyond loops and can serve to account for other phenomena of morphology and phonology.

2.1.0.2 Affixation and Reduplication

In this system all affixation involves adding precedence links and segments to a stem[1]. Suffixation looks like (5-a), which shows the English plural, and infixation like (5-b), which shows the Atayal animate action focus to which we will return in ch.4. Crucially, (5-c), which shows the Indonesian plural, is how to represent reduplication. All three of these structure have to be handled by a serialization algorithm, in order to be actualized by the motor system, which selects a path through the graph to be sent to the articulators. The details of such a serialization algorithm would take us too far astray; I direct the reader to Fitzpatrick and Nevins (2004), and Idsardi and Raimy (2013) for formal proposals. The general intuition is that serialization attempts to traverse as many arcs of the graph as it can with as little redundancy as possible, hence why it follows the path with the affix in (5-a) and (5-b) rather than bypass it and why it takes the loop in (5-c) but does not loop more than once.

(5) a. 

b. 

c. 

For Raimy, the multiprecedence structures on the left can be built either by vocabulary items or by readjustment rules specified to add structures like (6) to a root (7) to give the form in (8). The moniker 'last segment' is an informal way to refer to that part of the affix that is responsible for attaching it to the stem in the right location. This was named a

[1]There are at least three uses of 'stem' in the literature. I will use the term 'stem' in the sense of e.g. Nida (1949, p.83), Pinker (1999, p.115-116, 295) to refer to any form onto which an affix can be added, and hence any affixation operation is adding an affix onto a stem

sticky end by Samuels (2009) and we will discuss this mechanism below.

(6) a. $\{\langle lastsegment, z\rangle, \langle z, \%\rangle\}$

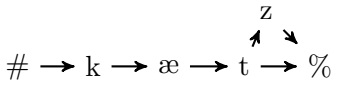
b. $lastsegment \rightarrow z \rightarrow \%$

(7) a. $\{\langle START, k\rangle, \langle k, æ\rangle, \langle æ, t\rangle, \langle t, END\rangle\}$

b. $\# \rightarrow k \rightarrow æ \rightarrow t \rightarrow \%$

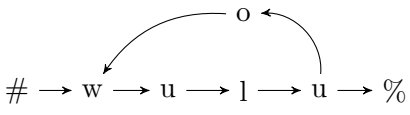
(8) a. $\{\langle START, k\rangle, \langle k, æ\rangle, \langle æ, t\rangle, \langle t, END\rangle, \langle t, z\rangle, \langle z, END\rangle\}$

b.

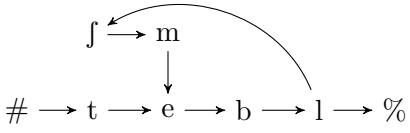


This representation can generate a vast number of patterns from numerous languages, like reduplication that adds phonological material between the copies such as the Bambara reduplication *wulu-o-wulu* 'whichever dog' <*wulu* 'dog' (Culy, 1985) in (9) or fixed segmentism in English *schm*-reduplication in (10), as well as account for a number of over- and under-application phenomena of phonology that McCarthy and Prince (1995) had claimed were not derivable in serial models. Raimy also shows how multiprecedence is restrictive enough to predict the impossibility of some unattested patterns that competing theories can easily generate. I will direct the reader to Raimy for a complete demonstration of the empirical coverage of Multiprecedence.

(9) *wulu-o-wulu*



(10) *table-schmable*



A crucial take-away of this theory is that according to it there is nothing special about reduplication as a word-formation operation. Affixation is adding material onto a stem, and reduplication is the case where that otherwise unremarkable affixation creates a loop in the representation. There is therefore nothing morphologically or phonologically special about reduplication, except for the fact that the representation it creates has a loop in its geometry. The link between the final /u/ an the intial /b/ in (5-c) is of the same nature as as the link between the /b/ and the /u/ that follows it. There is no special 'back arrow' symbol (*pace* Downing 2001 and Paschen 2018, p.3.

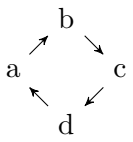
2.2 Detailed Mechanics

Before going beyond Raimy (2000), it is important that we take the time to examine the machinery of multiprecedence.

2.2.0.1 Start and End

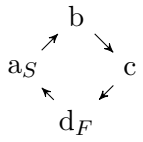
The Start and and End symbols are probably the most glaring difference between the graphs used so far and classical phonology based on strings. Those symbols are necessary in the multiprecedence model, because when loops are involved there is no way to know where to start without an explicit symbol. For instance in (11) it is impossible to decide where to start and end the loop; the only way is to mark segments as initial and final. There are multiple ways this could be done.

(11)



A simple way would be to directly mark it on the segments by augmenting the graph with a representation for initials and final states borrowed from Finite State Automata as in (12).

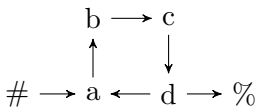
(12)



This makes it an information about the node itself whether or not it begins the word. One empirical problem with this approach is that the first and last segments of the out put form can change, e.g. through the addition of prefixes and suffixes.

Another possibility is to add a sort of empty segment as in (13).

(13)



This gets around the empirical problem, as material can be added between these empty segments and the overt phonological material of the stem.

One may be tempted to see this as a deficiency of the graph model, but phonological models based on strings also need boundary symbols, typically both marked with #, to which phonological rules may be sensitive. Even outside of the world of phonology having special start- and end-of-string characters are a common way to deal with strings in computer implementations of string, e.g. null-terminated strings in C. in order to dal with strings in a formal way the implementation always has to handle the start and end of the string in a special way. This is a case where multiprecedence is more explicit, not more complex. This is a distinction to which we will return in 2.3.0.1

2.2.0.2 Sticky-Ends

An important mechanics of Raimy's system is the *sticky end*, the part of the underlying form of affixes that allows them to attach onto a stem. The name 'sticky-ends' is from Samuels (2009) and I will borrow it here. It largely builds on the notion of pivot points from Yu (2003).

Sticky-ends are needed in this system for all affixes that attach to anything else than #

or %. Because sticky-ends can attach to multiple stems, they cannot know in advance what segment they attach to, and as such they must specify their target intensionally through the target's feature and/or relation to other segments within the form.

For instance suffixes must be specified to precede %, but also to follow the last segment of the stem, as in (6) above. This is done through a sticky-end that picks out the last segment of a word. This can be defined intensionally by making the sticky-end seek a segment x satisfying the relation $x \rightarrow \%$. Thus (6) could be more properly represented as (14) with one sticky-end seeking a segment that precedes %, and one end that seeks %.

(14) $[\_ \rightarrow \%] \rightarrow z \rightarrow \%$

These sticky ends can also be specified to seek segments with particular features. Consider infixation in native roots in Tagalog as in (15)[2].

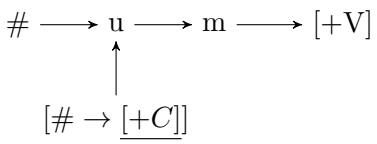
(15) Tagalog *um*-infixation (Kager (1999), citing French (1988))

alis	um-alis	'leave'
tawag	t-um-awag	'rewarded'

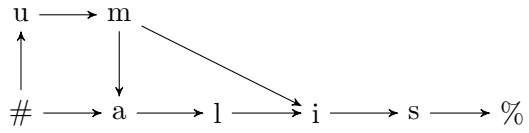
This can be handled with the affix in (16). This affix has three ends. One simply targets the beginning of the word, then the sticky-end pictured to the right seeks segments that are vowels. And finally the sticky-end pictured at the bottom seeks segments that both follow the # and are consonants. Note that not every stem will have such a segment, e.g. vowel-initial roots, in which case that sticky-end will simply be unable to attach. This is in fact exactly what we see in the formation of *um-alis* in (17). The affix attached to # and to every vowel of the word, that is, it added an ordered pair between # and /u/, as well as an ordered pair between /m/ and each of the vowels of the stem. But there was no segment in the stem satisfying the conditions of the other sticky-end which therefore did not add any precedence pairs to the graph. The affix in (17) thus ends up following # and preceding /a/, because this order satisfies all the precedence relations stated in the graph, thus surfacing as a prefix.

[2]Non-native roots, which may have onset clusters and have been reported to have variable realizations (e.g. Klein (2005), introduce some complications that would take us beyond the scope of this introduction.

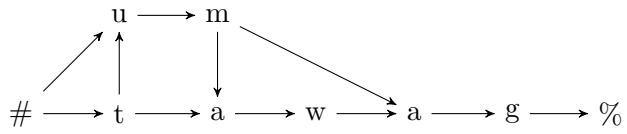
(16) Tagalog *um*-infix



(17) *um-alis*



(18) *t-um-awag*



In the formation of *t-um-alis* in (18) on the other hand all ends of the affix manage to attach, adding a link from # to /u/, one from /t/ to /u/, and one from /m/ to every vowel of the stem. the affix -um- therefore ends up following /t/ and preceding the first /a/, because this order satisfies every ordering relation stated in the graph, and thus it surfaces as an infix between these segments.

I will use the square brackets for sticky-ends. This usage is intuitively closely related to the use of square brackets in classical phonological rules, in which forms like [+high, -back] are meant to capture not a segment, but a natural class, namely an intensional description. In fact the square brackets are ambiguous as they are also used to refer to segments qua feature bundles. Here I will follow the convention of Bale et al. (2014) and reserve square brackets for intensional definitions (both in rules and in sticky-ends), and use curly brackets to refer to segments qua feature bundles. Thus from now on, [+high, -back] refers the set of all segments that are supersets of the set {+high, -back}, whereas {+high, -back} refers to sets of features, namely segments.

More formally one can read brackets as denoting properties, and sticky-ends as machines seeking segments with those properties. Consider the following properties:

- $\underline{[+F]}$ is the property of having feature $+F$,
- $\Big[[+F] \rightarrow \_\Big]$ is the property of following a segment with the property of having feature $+F$,
- $\Big[[+F] \rightarrow \underline{[+G]}\Big]$ is the property of having feature +G and following a segment with the property of having feature $+F$,
- $\Big[\_ \rightarrow \Big[[+F] \rightarrow \_\Big]\Big]$ is the property of preceding a segment with the property of following a sement with the property of having feature +F,
- $\Big[[+G] \rightarrow \underline{\Big[[+F] \rightarrow \_\Big]}\Big]$ is the property of following a segment having feature +G and following a segment having feature +F,
- $\Big[\Big[\_ \rightarrow [+G]\Big] \rightarrow \underline{\Big[[+F] \rightarrow \_\Big]}\Big]$ is the property of i) preceding a segment that has the propoety of preceding a segment having feature +G and ii) following a segment having feature +F,
- ...and so on.

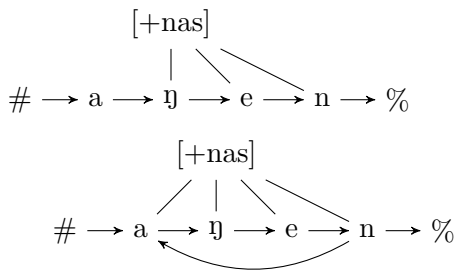
This is obviously too powerful. This is simply a way for me to describe the sticky-ends I need. Attempts have been made at working out a restrictive theory of sticky-ends in Multiprecedence by Yu (2003) and Samuels (2009) and I trust that they are on the right track, but I occasionally need more sensitivity to context and features than they do so I take the liberty of employing powerful sticky-ends and let the issue of working out their limitations to further research. This thesis is about the geometry of representation. Any more restricted system of sticky-ends capable of generating at least the ones I need in this dissertation will be good enough.

2.2.0.3 Raimy (2000) is not PROP

Raimy's (2000) phonology contains more than the precedence relation introduced in 2.1. Raimy maintains autosegmental assumptions of layers of elements associated to each others,

hence it relies on relation other than precedence. For instance the following appears in his analysis of Malay nasal harmony.

(19) Autosegmental feature spreading in Raimy(2000,p.18)



Raimy also did not conceive of the back arcs as independent morphemes, but as the effect of readjustment rules (p.4), but already in Harisson and Raimy (2004) there is a defense of reduplication arcs as morphemes and reduplication as a fully item-and-arrangement phenomenon. PROP however goes much farther in this assumption as wel will see in the following chapters.

2.3 Going Full PROP

2.3.0.1 Simplicity vs. graphics vs. power

I am claiming that the repsentational system of (20-b) contains fewer stipulations than one for (20-a). To understand this claim it is important to distinguish a) the fact that directed graphs are less stuipulative (and thus simpler) than strings in the way mentioned above from b) the graphical conventions of our writing system that allows us to easily represent strings as left-to-right lists of symbols, and c) the richer set of structures allowed in graphs than than in strings. a) is a mathematical fact about the properties of the data structure. Strings are graphs with a total order relation, namely the relation is total, transitive, and antisymmetric. A graph without these properties is a simpler mathematical object with fewer assumptions. It is true that thanks to b) we can represent strings in fewer symbols than graphs as in (20-a), but that is because our writing system implicitly packages all these stipulations, representing linear order in time as linear left-to-rightness on a the page.

We should not allow this purely pictorial fact of writing to influence impressions about complexity. Strings do require a logical relation of precedence between pairs of elements as well as a notion of start and end; the graph notation is simply actually writing those down. The presence of arrows and special START and END symbols in (20-b) is explicitness, not complexity.

(20) a. kæt

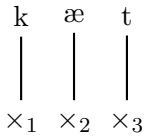
b. # → k → æ→ t → %

And as said in c) it is true that we can do more with less stipulative graphs than with strings (since all strings are graphs but not vice versa). As seen above graphs can contain branchings, loops, and parallel paths that strings cannot represent. But this is representational power, not complexity. My claim is that talking about generic graphs rather than strings is making fewer assumptions about what phonology is and therefore it is a simpler claim. But it is indeed powerful. Simpler things often offer more possibilities. The point of this paper is to argue that this power matches very well with all the less string-like phenomena of phonology and morphology that are attested. This simpler-than-string phonology is powerful, and it seems to contain just the right power to do morphology.

2.3.0.2 Complexity and power in phonological representations

It is already standard for phonology to be made more powerful than strings, thanks to autosegmental phonology, morphological planes, feature geometries, prosodic structures, and Optimality Theory correspondence relations. But all those approaches add this power by also adding stipulations to the representation, adding new relations, types, and restrictions, and therefore complexity in the above sense. For instance a representation like in (21-a) contains at least two types of relations: the more stipulative linear precedence relations between melodic segments and between timing slots, and the arcs connecting melodic segments and timing slots. This representation is at least as complex as (21-b-c), where P is the set of precedence statements and A is a set of autosegmental associations.

(21) a.

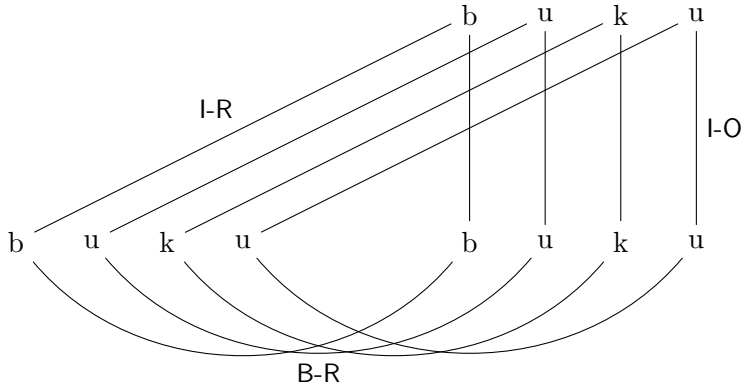


b. $\langle P, A \rangle$

c. $\langle \{\langle START, k\rangle, \langle k, æ\rangle, \langle æ, t\rangle, \langle t, END\rangle, \langle START, \times_1\rangle,$
$\langle \times_1, \times_2, \rangle, \langle \times_2, \times_3\rangle, \langle \times_3, END\rangle, \},$
$\{\langle k, \times_1\rangle, \langle æ, \times_2\rangle, \langle t, \times_3\rangle\}\rangle$

Similarly a typical representation from Optimality Theory contains multiple types of relations between segments, including precedence and any graph-theoretic relations used above, but also the relations of correspondence including Input-Ouput (I-O), Base-Reduplicant (B-R), and sometimes Input-Reduplicant (I-R) . A basic reduplicated structure like (22-a) will therefore be computed over a representation as complex as (22-b) with a set of all the precedence relations in the input and output, the I-O correspondences, the B-R correspondences, and the I-R correspondences as a bare minimum, which can be expanded as (22-c), the actual representation over which correspondence theory needs to be computed (see Raimy and Idsardi (1997).

(22) a. OT correspondences



b. $\langle P, IO, BR, IR\rangle$

c. $\langle \{\langle START^{input}, b_1^{input}\rangle, \langle b_1^{input}, u_2^{input}\rangle, \langle u_2^{input}, k_3^{input}\rangle,$
$\langle k_3^{input}, u_4^{input}\rangle, \langle u_4^{input}, END^{input}, \rangle, \langle START^{output}, b_1^{red}\rangle,$
$\langle b_1^{red}, u_2^{red}\rangle, \langle u_2^{red}, k_3^{red}\rangle, \langle k_3^{red}, u_4^{red}\rangle,$

$\langle u_4^{red}, b_1^{base}\rangle, \langle b_1^{base}, u_2^{base}\rangle, \langle u_2^{base}, k_3^{base}\rangle,$
$\langle k_3^{base}, u_4^{base}\rangle, \langle u_4^{base}, END^{output}\rangle\},$
$\{\langle b_1^{input}, b_1^{base}\rangle, \langle u_2^{input}, u_2^{base}\rangle, \langle k_3^{input}, k_3^{base}\rangle, \langle u_4^{input}, u_4^{base}\rangle\},$
$\{\langle b_1^{base}, b_1^{red}\rangle, \langle u_2^{base}, u_2^{red}\rangle, \langle k_3^{base}, k_3^{red}\rangle, \langle u_4^{base}, u_4^{red}\rangle\},$
$\{\langle b_1^{input}, b_1^{red}\rangle, \langle u_2^{input}, u_2^{red}\rangle, \langle k_3^{input}, k_3^{red}\rangle, \langle u_4^{input}, u_4^{red}\rangle\}\rangle$

As such, PROP representations like (23) are intended to be both more explicit about the information they contain, and simultaneously containing less information total.

(23) a. kæt

b. $\{\langle START, k\rangle, \langle k, æ\rangle, \langle æ, t\rangle, \langle t, END\rangle\}$

c. $\# \rightarrow k \rightarrow æ \rightarrow t \rightarrow \%$

In a way, the goal of this paper is to embrace the added power of PROP without introducing the added complexity of its competitors. All the phenomena that have led to doing phonology on graphs, tones, vowel harmony, floating features, make a convincing case in favor of something more powerful than strings in phonology, and we will return to those phenomena in the upcoming chapters. But instead of gaining this representational power by adding machinery, creating what are essentially strings with stuff around them, I propose that we do it by relaxing the stipulations on the string representation. If the limitations of strings can be circumvented either by adding complexity or by removing it, the latter is definitely a sensible direction to explore. Let's add power by simplifying.

2.3.0.3 THESIS: PROP is exactly what we need for language

The main thesis of this dissertation is this: the range of phenomena of morphology and phonology is exactly that which follows for free from the assumptions (or lackthereof) of PROP. The power of morphology and phonology reduce to the possible configurations of a PROP directed graph. The different geometrical configurations that a string cannot represent but that can be represented in PROP will capture exactly the range of non-concatenative morphology and non-linear phonology.

Chapter 3

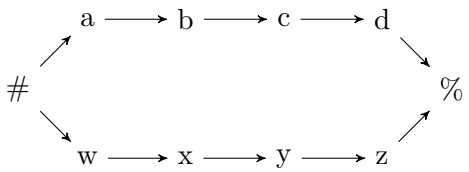
Tone and Harmony

In this chapter I will show that the representational power of PROP can derive phenomena of harmony and word-level tone from simple geometrical configurations made available for free by directed graphs.

3.1 Basic geometry

Expanding upon the representational possibilities of PROP, a geometrical pattern that can now exist is one containing separate streams, each of which contains phonological material. I will propose here that this representation is capable of accounting for tone spreading phenomena and harmony patterns.

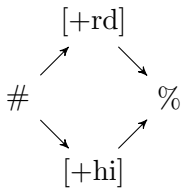
(1)



For the case of graphs without loops like (1) in which the the relation described by the graph is a partially ordered set, I will refer to incomparable elements of the partial sets –those pairs x,y in the graph for which is is neither stated that x transitively precedes y nor that y transitively precedes x– as being in parallel. The assumption I propose to follow here is that parallel nodes can surface simultaneously as long as they are phonetically compatible,

such that

(2) possible phonological form giving rise to surface {+rd,+hi}.



Intuitively, the claim is that the phonetic output of a graph like (1) is a surface form in which *abcd* is more or less coextensive in time with *wxyz*. The phonology does not transmit any ordering relation between the two to the motor control systems, and as such they are coextensive in time.

However coextensivity is too strong of a claim. A bit less restrictively, since the output of the phonology specifies nothing at all about the order it is up to the motor planning of the muscles involved in the realization of phonological material to produce an output that satisfies the input as they 'want'. In many cases the result will not be perfect simultaneity, as the motor movements of some features may be incompatible, or some motor movements faster or slower than others. If in (1) the features of *a* and *w* cannot be produced simultaneously, then one or the other will have to wait. We will come back to this discussion as we see more concrete examples.

3.2 Basic examples

3.2.1 Mende tone melodies

Since Leben (1973, 1978) nouns in Mende (Bantu) are commonly analysed as having one of five tone melodies, sequences of L(ow) and H(igh) tones, normally couched in Autosegmental

Phonology[1].

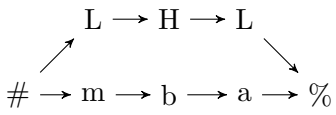
(3)

pattern	σ	$\sigma\sigma$	$\sigma\sigma\sigma$
H	kɔ́	pɛ́lɛ́	háwámá
L	kpà	bɛ̀lɛ̀	kpàkàlì
HL	mbû	kényà	fémàlà
LH	mbǎ	nìká	ndàvúlá
LHL	mbə̂	nyàhâ	nìkílì

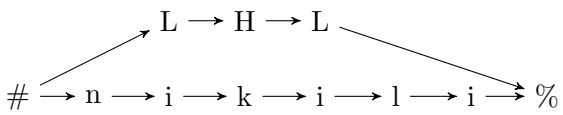
(from Odden, 1995)

The PROP analysis consists in seeing the tone melody as a parallel stream from # to %. This captures the notion of the independence of the tonal pattern from the segmental material behind the autosegmental analysis while using the simpler PROP representation. Intuitively we can see that once this type of graph is sent to the articulators, the segmental and tonal material are pronounced relatively independently.

(4) mbə̂



(5) nìkílì



All that the representation encodes is what precedes what. The melodic autosegments are ordered with regard to each others, and the tone autosegments are ordered with regard to each others, but the tones and the melodic autosegments are not explicitly ordered with

[1]Tones on a vowel V are notated as such:

- V́ = high tone
- V̀ = low tone
- V̌ = rising tone contour
- V̂ = falling tone contour
- V̰ = rising-falling tone contour

regard to each others. What the representation says is that both of them must occur between # and %. This captures the relative independence of Mende tone patterns from their melody. This is enough to capture the set of contrasts in Mende. It is however *not* enough to completely derive the phonetics. For instance I have provided no explanation as to why none of the tones ends up surfacing on the /m/ of (4), which is perfectly plausible phonetically. The important concern for me here is that the above captures the set of contrasts of Mende. The details of implementation is less important and could be done in many ways, including language-specific phonetic conventions in which the speaker knows to pronounce these graphs in the right way, or phonological rules that add other precedence links to ensure that everything aligns as it does on the surface. I will leave this as an open question.

3.2.2 Vowel Harmony in Akan

Beyond independence of some material, PROP also easily derives 'spreading' phenomena (here used in a descriptive sense). Consider Akan (Kwa) [ATR] harmony. The general pattern is for stems to be specified for [ATR] or not, which controls the form of both prefixes (6) and suffixes (7).

(6) Akan prefix harmony

	eat	be called
1s	mi-di	mɪ-dɪ
2s	wu-di	wʊ-dɪ
3s	o-di	ɔ-dɪ
1p	ye-di	yɛ-dɪ
3p	wo-di	wɔ-dɪ

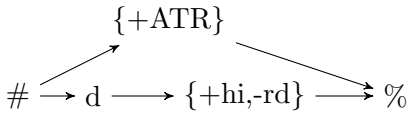
(7) Akan suffix harmony

wie	‘to finish’
a-wie-i	‘the end’
tɔ	‘to fall’
a-tɔ-ɪ	‘West’

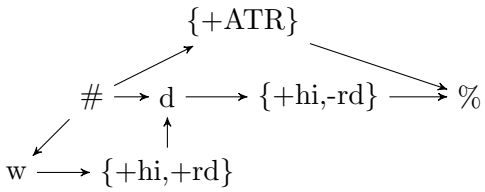
The forms in (6) show two roots that minimally differ in that the root for ‘eat’ is underlyingly +ATR and the root for ‘be called’ is underlyingly -ATR. The person agreement prefix agrees in ±ATR with the root. The forms in (7) show that the same harmony affects suffixes, demonstrated with the nominalizer.

This is easy to account for in PROP with roots specified for $\pm ATR$. For a root like eat (8) that is specified with $\{+ATR\}$ between and %, any prefix inserted between and the first segment will also be parallel to the $\{+ATR\}$ value ((9)).

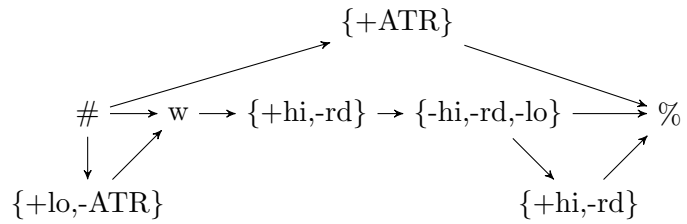
(8) $\sqrt{di}$



(9) wu-di



(10) a-wie-o



The reason the above graphs work is that the $\{+ATR\}$ feature, being specified only as following and preceding %, is parallel to everything that also occurs between those} symbols. In (9) we can see that there is a path from to % going via the $\{+ATR\}$ node and a completely separate path from to % going through the $\{+hi, +rd\}$ segment of the prefix. This gives us automatic bidirectional spreading.

Intuitively, the realization of this type of graph involves pronouncing a $+ATR$ value throughout the word that will surface whenever it does not conflict with other features, e.g. those of the consonants. Motor planning is told to move the tongue root to produce $+ATR$ in an event that follows the start of the word and precedes the end of the word. Since the two vowels are underlying underspecified for ATR the parallel $\{+ATR\}$ node will surface during those. One can imagine each stream as a part in a musical ensemble. The $[+ATR]$ is "played" throughout on one part, while the other stream "plays" the other segments. This rough analogy breaks down when it comes to resolving conflicts between multiple streams. We will see how these are resolved.

It is worth noting that I am therefore defending a view of harmony patterns in line with Lightner (1965), what he calls harmony as a property of root-morphemes. It is a property of morphemes and their lexical specification that makes them cause harmony phenomena, not directly a property of the co-occurence of segments and features involved. In this chapter we will see examples of disharmony and harmony controlled by morphemes lacking paraticipating segments that pose an problem to a theory of vowel harmony based on segment co-occurence restrictions.

3.2.3 Siane Tone patterns

This simple type of spreading is more common with harmony patterns, but it is attested for tone patterns in James' (1994) analysis of Siane (Trans-New-Guinea) (cited in Cahill

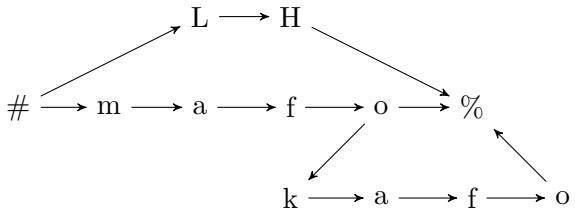
(2000)). In this language noun stems come with one of the tone patterns H, L, LH, HL, or HLH and the generalization is that the first tone is realized on the first syllable and the last one on the rest, including the suffixes. The exceptions are the case of HL words over four syllables in which case the two first syllables carry H and the rest L. and the case of bi-syllabic HLH words which seem to mostly surface HL-H rather than H-LH.

(11)

	noun stem	1p.poss.	defin	erg	gloss
H	kúlá	kúláté	kúlámá	kúlákáfó	'dog'
H	kétúfú	kétúfúté	kétúfúmá	kétúfúkáfó	'saliva'
L	mèinà	mèinàtè	mèinàmà	mèinàkàfò	'payment'
L	kòsìnà	—	kòsìnàmà	—	'sky'
LH	màfó	màfóté	màfómá	màfókáfó	'taro'
LH	kìlífú	kìlífúté	kìlífúmá	kìlífúkáfó	'trap'
HL	lónò	lónòtè	lónòmà	*lónókàfò*	'work'
HL	máfùnà	*máfúnàtè*	*máfúnàmà*	*máfúnàkàfò*	'owl'
HLH	kêfá	kéfàté	kéfàmá	kéfàkáfó	'meat'

The PROP analysis of this pattern combines the insights of Mende and Akan and starts with a parallel stream of tones for each root's pattern with the suffixes added in parallel to those. The string of segments /mafokafo/ is being pronounced while the sequence of tone /HL/ is also being pronounced.

(12) màfókáfó



One may wonder why the tone melody tone is realized as it is with a low tone on one syllable and a high tone on three syllables. That is, why doesn't the graph in (12) predict

[màfòkáfó], with a low tone on two syllables and a high tone on the other two as in the HL case of [lónókàfò]. After all, if two tones have to be pronounced during four syllables, one could well think that they would get two tones each. However the formal system here makes no such claim. All that the graph says is that a sequence of tones /LH/ must be pronounced between the beginning and the end, and a sequence /mafokafo/ must be pronounced between the beginning and the end, nothing else. It might be that we need to formulate phonological rules that would add the required ordering relations, but ideally there is nothing more to say about how that happens at the level of the phonology if it is resolved by phonetics and motor planning.

In other words I contend that the choice between all configurations of a sequence of /HL/ tones pronounced over four syllables is chosen for non-linguistic reasons in a motor-planning module. There are problems, such as how to get the tones to align in the exact way they do. For instance why is the HLH form *kêfa* HL-H rather than H-LH *kèfă* The question of how this may be done is a topic for further research. It is sufficient here to derive the contrasts.

3.2.4 Finnish Transparent vowels and Turkish opaque vowels

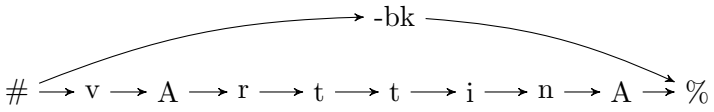
One assumption I made at the beginning of this section is that parallel segments are constrained by phonetic compatibility: two parallel segments will not be pronounced simultaneously if their features are incompatible. For the purpose of this thesis this is simply the impossibility of performing two gestures that cannot be peformed at the same time: if the consonant holds features incompatible with tone or vowel specifications, then those tones cannot be simultaneous to those segments.

However one very strict and simple use of this principle is in the case of transparent vowels, vowels that are seemingly ignored by vowel harmony, where featural specifications of two segments in parallel can be explicitly contradictory.

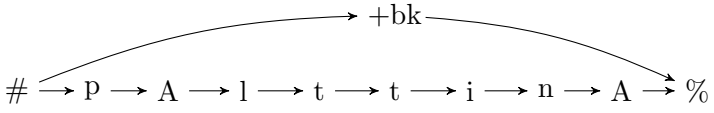
Consider Finnish backness harmony as described in van der Hulst and van de Weijer (1995). Roots are segregated into front vs. back, such as *värttinä* 'spinningwheel' vs. *palttina* 'linen cloth', which will surface respectively with front affixes, *värttinä-llä-ni-hän*, 'with spinning wheel, as you know', or back affixes, *palttina-lla-ni-han* 'with linen cloth, as

you know'. The underlying forms of these roots would be as in (13) and (14), where /A/ stands for a low vowel underspecified for backness[2].

(13) *värttinä*

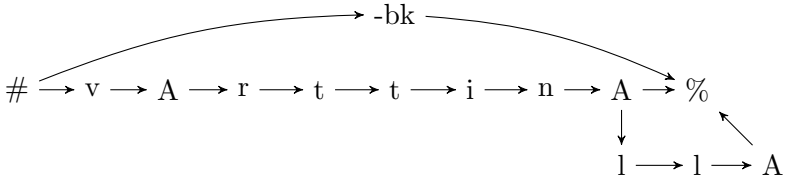


(14) *palttina*

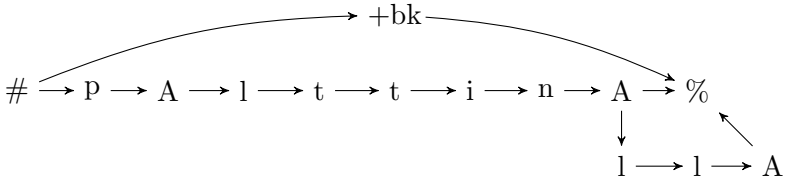


As expected the back feature will have 'scope' over suffixes and create the harmony pattern:

(15) *värttinä-llä*



(16) *palttina-lla*



Note that /i/ is unaffected by vowel harmony. This is easy to explain if we posit that Finnish /i/ is underlyingly -back. Because the +back autosegment and the -back /i/ cannot be coextensive, only one of them will surface at that point in time, here the segment's for

[2]I am not concerned here with the issue of underspecification, which may easily allow one of the two classes of Finnish words to be underspecified for backness and simplify the analysis.

a reason that will become clear.

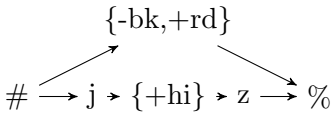
Now consider the case of opaque vowels, vowels that not only do not harmonize, but create their own domain of harmony. In the well known case of Turkish, vowels harmonize for backness and roundness, as shown in (17) with the genitive suffix *-in/-yn/-ɯn/-un*. The plural suffix *-ler/-lar* however assimilates only in backness. It is always -Round, but it is not transparent to roundness harmony; a genitive suffix following a plural suffix will surface as -round, regardless of the root and of how it surfaces in the singular genitive, as in the crucial case of *jyz-yn* vs. *jyz-ler-in* as opposed to **jyz-ler-yn*.

(17)

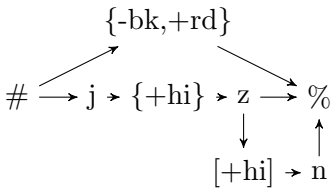
nom.sg.	nom. pl.	gen. sg.	gen. pl.	gloss
ip	ip-ler	ip-in	ip-ler-in	'rope'
jyz	jyz-ler	jyz-**yn**	jyz-ler-**in**	'face',
kɯz	kɯz-lar	kɯz-ɯn	kɯz-lar-ɯn	'girl'
pul	pul-lar	pul-**un**	pul-lar-**ɯn**,	'stamp'

The PROP analysis of the roots and genitives is straightforward given what we have seen so far: the root must be specified to have parallel ± back and ± round features as in (18). The genitive is then added to such forms to give (19), and the underspecified vowel is pronounced with the values of the segment it is parallel to.

(18) $\sqrt{jyz}$



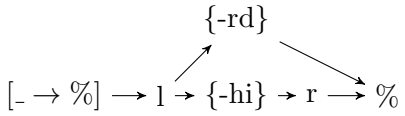
(19) *jyz-yn*



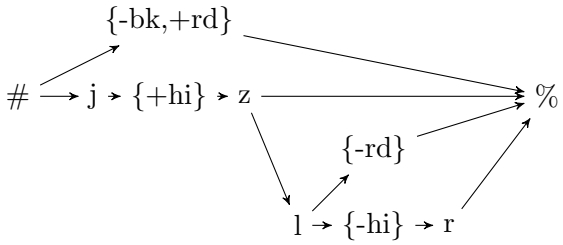
The plural introduces some complication: it contain a -round feature to 'protect' it from

harmony as in the Finnish case above, but this -round feature must also be parallel as its roundness makes subsequent suffixes harmonize. It will therefore have the underlying form in (20), with its [–round] feature scoping over any further suffix. If affixed to a root $\sqrt{jyz}$ it will attach as in (21).

(20) *-lAr*

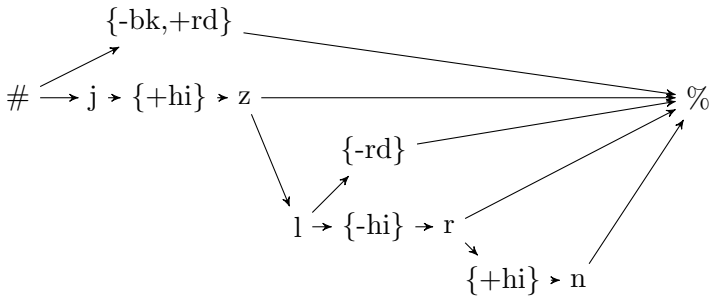


(21) *jyz-ler*



Finally to this form we can affix the genitive as in (22).

(22) *jyz-ler-in*

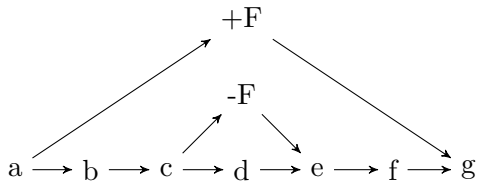


The graphs in (21) and (22) are starting to be complicated, but it is pretty straightforward: the [-bk,+rd] portion of the root emcompasses the whole form, and the [-rd] portion of the suffix encompasses everything after the /l/ of -lAr. But now we reach an issue of phonetic realization: at the point of pronouncing the $\{-hi\}$ segment of the plural and the [+hi] segment of the genitive, these segments are parallel to *both* the $+rd$ of the root *and*

the $-rd$ of the suffix, so why do they surface as [-rd]?

I propose that it is a general fact of the phonetic realization of parallel contradictory features that the "inner" one always wins. More precisely: if all the segments parallel to A are also parallel to B, but not vice versa, and A and B contain a feature with contradictory values then for the segments that are parallel to B it is B that will be pronounced in parallel. For instance in a configuration like (23), in which all the segments parallel to segment $\{+F\}$ are also parallel to segment [-F] but not vice versa, it is 4 $\{-F\}$ that 'counts' during the segments parallel to -F, namely /d/, thus it will surface as in (24).

(23)



(24)

[a $\longrightarrow$ b_{+F} $\longrightarrow$ c_{+F} $\longrightarrow$ d_{-F} $\longrightarrow$ e_{+F} $\longrightarrow$ f_{+F} $\longrightarrow$ g]

Importantly, the case of transparent segments discussed above is just the extreme case of this principle where there is no segment /d/ and the inner segment with a contrary feature surfaces on its own as in the Finnish example in (16). We therefore unify the 'independence' of transparent and opaque segments from harmony out of the same geometric principle. Or seen in another way opaque segments are nothing more than segments with both the property of having an 'inner' feature like a transparent segment, and the property of having this feature stretch to one edge of the word like a 'spreading' feature.

Ideally we should hope to derive this principle of phonetic realization independently. We will come back this in section 8.1.

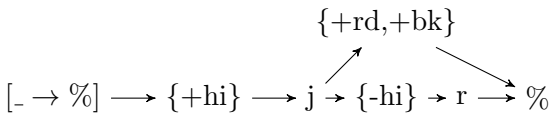
The facts of Turkish described so far also straightforwardly allow for so-called 'half-harmonizing' suffixes such as the progressive suffix as in (25) described in Clements et al.

(1982, p.231) and Nevins (2010, p.34), which is adequately accomplished with an affix such as (26).

(25)

g^{j}el^{j}-ijor-um	'come-PROG-1SG'
ko-ujor-um	'run-PROG-1SG'
gül^{j}-üjor-um	'laugh-PROG-1SG'
bak-ɨjor-um	'look-PROG-1SG'

(26) *-Ijor*



This suffix will create a new harmonic domain to its right, but the first vowel is not within that scope and will follow the parallel features of the root (or potentially previous suffixes). This shows that although the PROP analysis makes vowel harmony a fact of the morpheme rather than the segments involved, it is not so coarse as to allow only entire morphemes to be harmonizing or not. PROP allows for flexibility in the representation of what harmonizes and how.

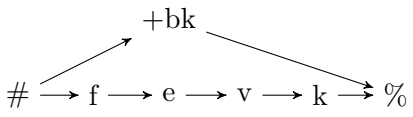
3.2.5 Disharmony and Antiharmony

A natural consequence of the mechanics defined above is that the mechanism of vowel harmony and that of transparent neutral vowel are independent. We therefore predict that a root can trigger harmony while containing no vowel that participates in it. Disharmony and antiharmony are well attested phenomena that are often relegated to a list of 'exceptions' to the harmony.

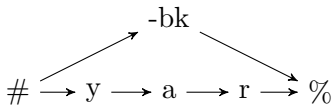
For example in Turkish several roots borrowed from Arabic or French have front vowels and take back suffixes or vice versa. (Lewis, 1967, p.17-18) gives multiple examples such as *fevk* 'top', *fevkı* 'top.acc', with a front root vowel and back endings, and *yâr* 'beloved', *yâri* 'beloved.acc', with a back root and front suffixes. In PROP they are simply represented as

in (27) and (28), with the root vowel containing a specification for $\pm bk$ that wins over the parallel feature.

(27)



(28)



Other well-known instances of disharmony is the case of roots with front vowels that take back affixes in Hungarian. While some roots with /i/ or /e/ behave as one would phonetically expect and take front sufixes like *vi:z* 'water' *vi:z-ek* 'waters', some do the opposite, e.g. *hi:d* 'bridge' *hi:d-ak* 'bridges'. The form of the affix is not predictable from the surface.

It would be easy to dismiss these examples as 'exceptions' and 'non-native vocabulary', but this is not an *account* of them. These forms are still part of the language and used productively by native speakers. They must have a representation that can combine with the representations of the suffixes. In many theories this is ignored, but in PROP these forms can be given an explicit underlying representation that will derive their behaviors.Phonology needs to be powerful enough to encode this type of arbitrariness between roots and the harmonic feature they impose. In PROP this is easily accounted for with a parallel affix.

A final note on disharmony is that PROP allows for artitrary disharmony in a language with vowel harmony. In many languages there is a tendency for disharmonic stems to take suffixes patterning with the final vowel. Thus e.g. the Hungarian root *ʃofœr* 'chauffeur/driver' with one back and one front vowel takes back suffixes: *ʃofœr-œk* 'chauffeurs/drivers'. But the opposite is also attested. in Tatar as described by Henry (2018), consistently mixed stems take suffixes that consistently pattern with the initial vowel. We

therefore cannot draw a universal conclusion about the linear locality of vowel harmony and phonological theory must be powerful enough to allow any patterns of disharmony with regard to whether affixes match with the first or last vowel of a root, or with any of them.

3.2.6 Underlying vs. harmonic rounding in Moloko

Another example of the independence of harmony and transparency comes from Moloko and described by Friesen (2017, p.40). Moloko roots come in three varieties: neutral, labialized, and palatalized, with a minimal triplet in (29) using Friesen's notation where ^{o} marks labializing morphemes and ^{e} marks palatalizing ones. Like many Central Chadic languages, Moloko is commonly analyzed as containing a single underlying vowel /a/ with unpredictable location, and epenthetic vowels with preditable locations. Labialization and palatalization descriptively spread to other morphemes as in (30) and affect the output of /a/, of the epenthetic vowels, and of some consonants.

(29) a. /kra/ [kəra], 'dog'

b. /kra ^{o}/ [k^{w}ʊrɔ], 'ten'

c. /kra ^{e}/ [kɪrɛ]

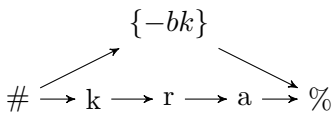
(30) a. /na - zɗ/ [nazaɗ], 'I take'

b. /na - zm ^{o}/ [nɔzɔm], 'I eat'

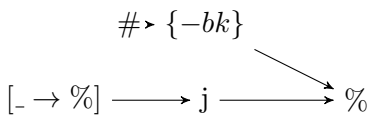
c. /na - s - j ^{e}/ [nɛʃɛ], 'I drink'

This is very straightforward so far. This simply calls for roots like (31) and affixes like (32).

(31)



(32)



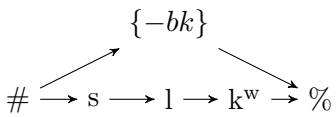
Labialization has a rounding effect on back consonants (velars asnd /h/), as shown with /k/ in (29-b). But Moloko also has underlying labialized consonants, which can mismatch with the melody of the root it is part of as in (33). There are therefore two source of labialized consonants in Moloko: they can be underlying, or they can be the result of harmony.

(33) a. /s l k^w ^{e}/ [ʃɪlœ k^w], 'broom'

b. /g^w la/ [g^wʊla], 'son'

c. /h^wa ɗa/ [h^woɗa], 'dregs'.

(34)



There can therefore be forms in which an underlying labialized consonant persists despite the root spreading palatalization to the rest of the word. Friesen cites the form [mɪ-sɪk^wøm-ɛ] (p.48), which has a labialized consonant and is otherwise palatalized throughout, except for the local rounding effect of underlyingly labialized consonants on following vowels.

Moloko therefore militates against views of vowel harmony as fundamentally a fact of interaction among *segments*. Most approaches to vowel harmony see the phenomena as restrictions on surface co-occurrence among segment classes, or as segments giving or copying features. But the facts of Moloko suggest otherwise: it is not a property of, for instance, [g^w] that it spreads or is a source of roundness, it is a property of roots that they carry or don't carry a round feature that spreads.

The forms in (34) are particularly problematic for search-and-copy approaches to harmony, because if harmony is triggered by a search from the underspecified segment to find a labialization value, in these forms the first segment it will find leftward or rightward is

going to be labialized, but this will yield the wrong result because the roots are palatalized or neutral. For instance the prefix part of the 1st person plural inclusive circumfix /ma-...-ok/ surfaces as [mɔ-] or [mʊ-] in labializing contexts, such as in (35). This contrasts with (36) in which the root does not trigger labialization and the prefix surfaces as [ma-][3]. A search-and-copy algorithm would have to say that the /a/ of /ma-/ seeks labialization to its right so as to account for (35). But then that predicts that it should find it in (36) as well. Moloko is therefore not straightforwardly analyzable in terms of search-and-copy.

(35) /ma - kaɬ- ak^{o}/

[mɔ́- k^{w}ɔɬ- ɔk^{w}]
1PIN+PVF - wait - 1PIN (p.42)

(36) máà - h^{w}ʊɮ- ɔk
1PIN+PBL - DESTROY - 1PIN (p.227)

It also will not help to parametrize the search algorithm, e.g. to make it ignore consonants and search for a vowel bearing a backness or rounding specification, because some of the morphemes triggering harmony consist of only a consonant.

(37) a. /v ^{e}/ 'pass'
b. [v-ɛ] pass[2S.IPM]-CL , 'pass!' (spend time)
c. [mɪ-v-ijɛ] NOM-pass-CL, 'year' (lit. 'passing of time') (p.131)

(38) a. /l ^{o}/ 'go'
b. [o-lo] 'he/she went' (p. 179)
c. [kʊ̀-lɔ̄-hɔ̄m] go, 2P perfective (p.403)

(39) a. /-j^{o}/ 'IMP'
b. [ndolo-j] 'explode.IMP' (p.180)

But while it is a problem for segment-oriented theories of harmony, root-based theories like

[3]For both (35) and (36), the perfective and possible moods are marked by the high tone and by the high-low+length of the prefix respectively

PROP have no problem, roots may have a parallel harmonizing feature, and disharmonic segments, and the two are not impediments to each other.

3.3 Plugging-in

The parallel graphs in the preceding section were all underlyingly parallel, i.e. the underlying form of the root contained multiple streams. However we can define affixes that attach in parallel to a root.

3.3.1 Parafixes

I will use the terms *parafix* to refer to an affix added onto a stem in such a way that its segments are parallel to some or all the segments of the stem. The term has been used for instance in analyses of Semitic templatic morphology along the lines of McCarthy (1981) to refer to the morphological process that adds morphemes in parallel to CV templates. It is important to keep in mind that in the analysis here there is nothing in the theory that distinguishes the content of the affix itself or its affixation process that creates parafixation, but it is useful to distinguish the geometrical pattern created by adding material in parallel to other material.

For instance Roberts (1994, p.93-94), Akinlabi (1996), and Nevins (2010) discuss the example of Kanembu in which the completive is $+ATR$ and the incompletive is $-ATR$.

(40) Kanembu from Nevins (2010)

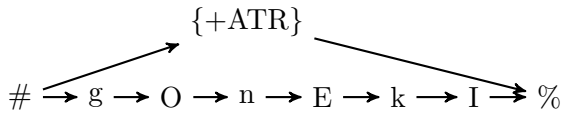
gɔnəkɪ	gonʌki	'I took / I am taking'
dalləkɪ	dʌllʌki	'I got up / I am getting up'
barrɛnəkɪ	bʌrenʌki	'I cultivated / I am cultivating'

This can be accounted for in PROP with an affix like (41-a) attaching in parallel to roots underspecified for $[+ATR]$ as in (41-b) (where /O/,/E/,/I/ stand for segments underspecified for ATR), giving graphs as in (41-c) with a similar geometry as the Akan example above. We can see that affixes are in a way 'plugged' onto the graph of the stem.

(41) a. $/\# \rightarrow \{+ATR\} \rightarrow \%/$

b. $/\# \rightarrow g \rightarrow O \rightarrow n \rightarrow E \rightarrow k \rightarrow I \rightarrow \%/$

c.



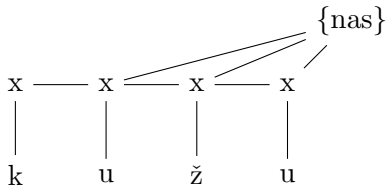
We saw in 2.2.0.2 that already for Raimy (2000) some affixes need to target segments other than at the edges of the form, e.g. for infixation and partial reduplication, by anchoring the affix to something other than # or %. As expected we can find cases where parafixes also target non-edge segments.

An important class of phenomenon that this kind of plugging in can easily derive is bounded spreading of certain features. Consider the regressive nasal spreading in Mixtec that Piggott (1992) calls a pseudo-harmony, triggered by the second person inflection.

(42) Mixtec regressive nasal spreading from Piggot (1992)

kũžũ	'you are diligent'
kĩʔvĩ	'you will be drunk'
kĩʔðĩĩ	'you will get angry'
kaʔcẽ tã	'you will sing'
kotõ^{n}dɛ̃ɛ̃	'you will examine'
cikweʔcẽ	'you will complain'
koʔšõ	'you will fall'

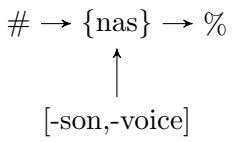
(43)



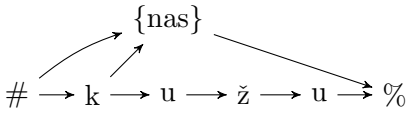
As shown in (42), the second person in Mixtec is marked by nasalization from the end of the word to the last voiceless obstruent. A straightforward autosegmental analysis of this pattern involves a second person suffix that spreads leftward until the a voiceless obstruent as in (43).

This can be handled in PROP with a second person affix underlyingly set to attach to voiceless obstruents as in (44). Note that the sticky-end here will seek *all* segments containing the features -sonorant and -voice. As such when attaching to the root $\sqrt{kužu}$ it will attach to the ends of the word, as well as to the /k/, thus the nas follows /k/ and precedes the end of the word, nasalizing everything in this span. But in the case of $\sqrt{cikwe?ce}$ the resulting graph is more complicated, but the ordering relation is easy to interpret: the {nas} segment follows multiple consonants, but in particular it follows the last /c/ and therefore it will surface after it. We could perhaps devise a way for the sticky end to pick out only the last such consonant, but this would lead to a more complex representation for (44) and there is no evidence for it, so I will stick to (44) even though it leads to the unexpected representation in (46).

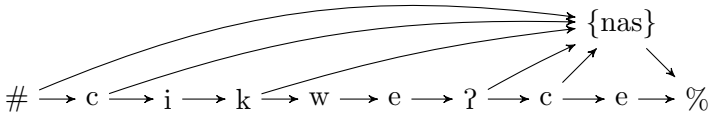
(44) Mixtec 2nd person affix



(45) kũžũ



(46) cikwe?cẽ



These very basic examples show that the power of PROP is at least sufficient to account for basic phonological patterns. The next section will turn to advantages of PROP over more traditional autosegmental accounts.

3.3.2 Tone Donation

The examples so far have been very basic phonological patterns that are also very well handled in autosegmental phonology. We will now turn to phenomena for which the PROP analysis is, I think, conceptually superior: cases where tones seem to need both a sort of independence from melodic content, and also some knowledge about linear order, giving rise to call the partial-independence problem: autosegmental theory allows only complete independence between autosegments or complete attachment. PROP on the other hand flexibly allows for intermediate levels of independence.

A relatively common phenomenon of tone phonology is donator morphemes. This phenomenon involves morphemes that contribute both a tone and segmental material, but the tone gets realized not on the segments it came with, but elsewhere on the final form, thus donating a tone to neighbours.

Consider KiYaka as described in Kidima (1991, p.19,35). Nouns that follow the class 7 prefix *kya* surface with a raised high tone on the stem[4].

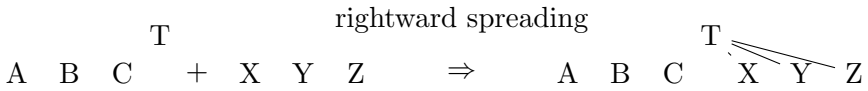
(47) KiYaka donating tone

'as for the __ as well'	'it's of the __'	
ndoongo pé	kya ndő́ongo	'needle'
ndoongo pé	kya ndoő́ngo	'palmwine'
zoba pé	kya zőbắ	'idiot'
ngoombe pé	kya ngoő́mbe	'cow'
katíká pé	kya kắtíka	'liver'

Before analysing this pattern it is worth bringing attention to a dangerous pitfall of autosegmental phonology when trying to deal with tone donation. Consider the abstract analysis in (48). It might look good at first, but it does not work: by autosegmental assumptions the tone /T/ and the segments /ABC/ it is floating over should be *unordered* with regard to each other. There is no sense in which /T/ could be to the right of /ABC/. Illustrating /T/ slightly to the right of /ABC/ would be an abuse of notation.

[4]KiYaka has three phonetic tones: V = Low, V́ = High, V̋ = Raised High (Kidima, 1991, 13-14).

(48) Bad autosegmental analysis of tone donation



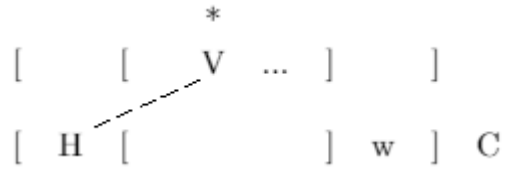
A first lesson to draw here is a call back to the discussion in section 2.3.0.1 above: there is a danger to letting some important relations like precedence remain implicit in the representation, because then we might not realize when we are letting something back in where it shouldn't be.

But to the point at hand, (48) cannot be the autosegmental analysis. Something has to force the floating tone to associate rightward.

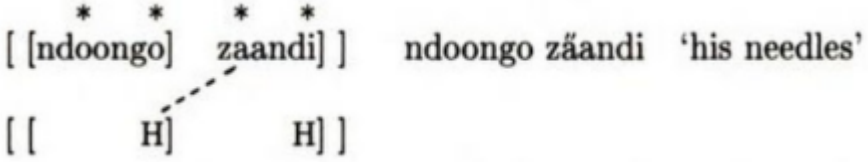
Kidima's analysis is with a process he calls H-Attraction (p.33) in (49). But it is not clear that this analysis should be allowed in autosegmental phonology. It requires a notion of floating tones being ordered with regard to material they are not associated with, which is obvious in examples such as (50) from Kidima (1990).

(49) Kidima's H-attraction rule

Associate a floating H to the first unlinked accented syllable to the right of its domain.



(50) Example of H-attraction from Kidima (1990)

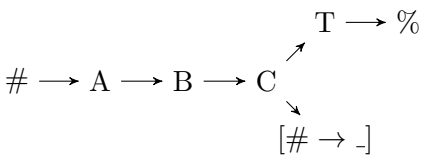


What I want to argue from this example is that an analysis of tone donation needs a way to encode phonological material that is *both* relatively independent from other phonological material *and* linearly ordered with regard to it, simultaneously. Autosegmental represen-

tations can only have one or the other: two phonological tiers are either independent and unordered with regard to each other, or associated and ordered with regard to each other. There is no halfway.

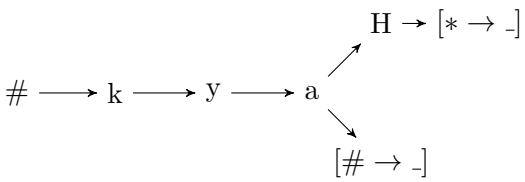
This is something that a PROP analysis does well. Consider the form in (51), which would accomplish what (48) purported to account for. Here I intend the notation [# → _] to stand for a sticky-end seeking a segment that has the property of following # (in the same way that traditional phonological rules use A_B to refer to a segment following A and preceding B). The advantage of this analysis is that it is possible to both maintain the independence of /T/ with regard to /ABC/, as well as order the two of them so /T/ is right of /ABC/.

(51) PROP version of (48)



With this kind of morpheme it is possible to account for the pattern in (47) as in (52), in which I informally use $*$ to represented an accented segment, thus putting the H in parallel to the first stressed segment[5].

(52) KiYaka class 7 prefix



An application of this type of tone donation can be see in Turkish to discuss is what Clements et al. (1982, p.239) attribute to consonant-conditioned harmony. Some roots are

[5]For simplicity's sake I omit here the fact that *kya* is taken by Kidima (p.19) to be a bi-morphemic combination of a class 7 prefix *ki-* and a morpheme *-a* whose role is unknown.

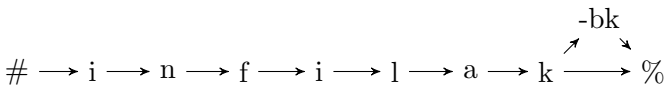
found with front suffixes even though their final vowels are back as in (53) (compare with regular [jatak]~[jata:gɨ], 'bed').

(53)

nom.sg.	acc.sg	gloss
infil^{j}ak	infil^{j}āk^{j}i	'explosion'
idrak	idrāk^{j}i	'perception'
ittifak	ittifak^{j}i	'alliance'

In Clements et al.'s system, the only option they have is to attribute the front harmony to a -back feature on /k/ that delinks word-finally. In PROP this is basically tone donation. Roots have forms as in (54), and suffixes will be placed in parallel to the -back feature. There is no need to worry about the k~ k^{j} alternation, as there is already a rule of Turkish that makes /k/ agree in backness with the tautosyllabic vowel.

(54)



More complex phenomena of tone donation at long-distances are possible. And for this we will analyze the case of Digo in more details.

3.3.3 Digo Verbal Tonology

Digo is a language with complicated word- and phrase-level tone phenomena. The following analysis is based on the data from Kisseberth (1984), but the presentation does not go in the exact same order and does not address the historical justification for parts of the analysis.

Digo possesses two main kinds of roots, some that are are underlyingly toneless and some that have an underlying high tone. The two types can be exemplified with the infinitive form marked with *ku-*. As is common in Bantu language all indicative verbal forms have a final *-a* morpheme. The forms in (55) are toneless and the forms in (56) and (57) have an

underlying high tone[6].

(55)

ku-changamuk-a	'to be cheerful'
ku-ambir-a	'to tell'
ku-dekez-a	'to spoil s.o.'

(56)

ku-furukŭt-â	'to move restlessly'
ku-arŭk-â	'to begin, start'
ku-bomŏr-â	'to demolish'

(57)

ku-dunduríz-a	'to place in reserve'
ku-furíz-a	'to apply heat'
ku-koróg-a	'to stir'

The presence of a high tone can manifest itself in one of two ways at the surface as seen in the difference between the rising-falling pattern in (57-a) vs. the high-low pattern in (57-b). A good reason to treat the two patterns in (56) and (57) as manifestations of the same tone ias that this difference is predictable: the high-low pattern occurs when the final consonant of the root is a voiced obstruent (depressor consonant) and the rising-falling pattern occurs elsewhere. We can also observe the underlying unity of the two patterns for forms in which a suffix is added to the root and the final consonant is thus not from the root. The derivational extension suffix -ir for instance can be added to toneless roots without adding any new tone as in (58-a). When added to a high-toned root ending in something other than a voiced obstruent the rising-falling pattern occurs shifted onto the extension as in (58-b). Finally when added to a form ending in a voiced obstruent, the tone is also shifted, but it now takes the form that we expect from a form ending in something

[6]For the rest of this section the morphemes that bring a High tone to the form are underlined

other than a voiced obstruent.

(58)
a. ku-vugur-a ‘to untie’
ku-vugurir-a ‘to untie for/with’

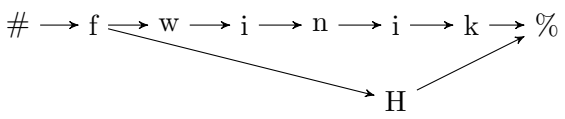
b. ku-fwinǐk-â ‘to cover’
ku-fwinikǐr-â ‘to cover for/with’

c. ku-bundúg-a ‘to pound’
ku-bundugǐr-â ‘to pound for/with’

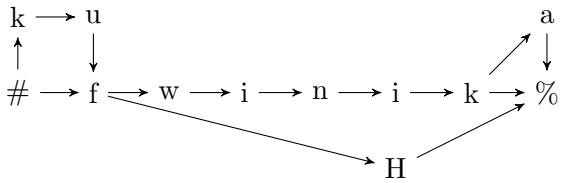
We can therefore conclude that all high-toned roots are underlyingly the same and a derivationally late effect causes the difference between the rising-falling and the high-low pattern to arise.

For the PROP analysis, I posit that underlyingly high-toned roots come with a H tone as in (59). Adding suffixes as in (60) and (61) puts them within the ‘scope’ of the high tone.

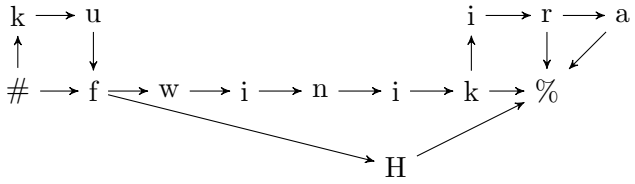
(59) $\sqrt{fwinik}$



(60) *ku-fwinik-a*



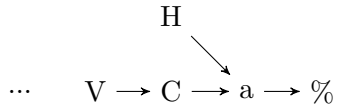
(61) *ku-fwinikir-a*



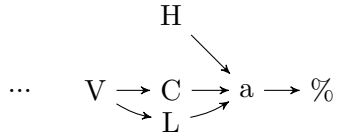
A process must then be responsible for narrowing down the H tone to the end of the

word so as to create the high-low vs. rising-falling patterns (as in the Siane case in (12)). The details of this process do not matter much for the present discussion, but one possibility is to take advantage of the fact that voiced obstruents in Digo can be argued to carry an L tone, as is common throughout Bantu (depressor consonants). If this is the case, and given a late process making tones that precede the end of the word precede the final vowel, the difference between the two final patterns can be ascribed to the difference between the schematic forms (62) and (63).

(62)



(63)



Pushing the idea that motor planning can bear part of the explanatory load, here is a simple account of this final pattern that follows from event timing. In (62) H must precede /a/. This can be done with the H pronounced with a peak on the consonant, which will mostly surface as rising-falling on the neighbouring vowels as in (58)[b]. But in (63) the H cannot be simultaneous with the consonant, as this consonant must already be simultaneous to a L tone, and it cannot be pronounced any later as it must precede the final *-a*, so it is planned to peak earlier on the vowel, resulting in the high-low pattern of (58)[c]. This analysis is obviously very speculative. Again this is a promisory note, with the hope that phonetics can do part of the work for us without having to totally specify the linear order of segments.

The evidence that this process is late is that the final patterns can actually surface on a following noun in Verb-Noun VPs. A complete analysis of full VPs would take us too far astray.

(64)

ku-onyĕs-â	‘to show’
n-jira	‘path’
ku-onyes-a n-jĭrâ	‘to show the way’

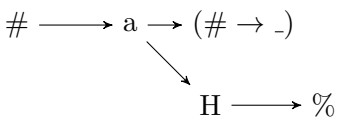
One thing worth appreciating here is that PROP allows such a thing as an analysis that is temporarily vague about the ordering of its material. A root can be introduced with an H between the beginning and the end, i.e. anywhere in the form, and remain incompletely specified until other affixes are added, after which a late process will narrow down the H tone to the end of the word (as opposed to having the whole form surfacing with a high tone as in the Mende and Siane examples discussed above). In a sense PROP brings underspecification to ordering. It is a theory in which order can be underlying underspecified. We will cover many examples of this idea in future chapters.

Digo also has object prefixes. The plural object prefixes come with a H tone that also surfaces at the end of the word. In the case of underlingly toneless words these forms surface with the same tone pattern as verbs whose roots have an underlying H tone as shown in (65) with a toneless root.

(65)

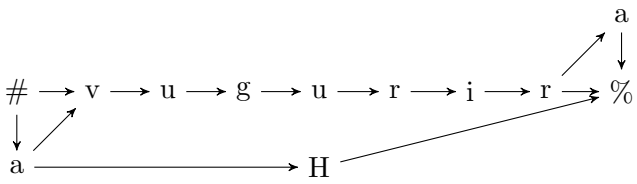
ku-vugurir-a	‘to untie for’
ku-ni-vugurir-a	‘to untie for me’
ku-ku-vugurir-a	‘to untie for you s.g’
ku-mu-vugurir-a	‘to untie for him/her’
ku-u-vugurĭr-â	‘to untie for us’
ku-a-vugurĭr-â	‘to untie for you pl.’

(66) Digo 1pl. object



The affix in (66) will attach to the root and also contribute an H tone parallel to the whole verbal complex. At the point in the derivation after affixing the plural the stem looks like (67)[7], very similar to the forms with a root H pictured above.

(67)



Interestingly, when this affix is added onto a root that does have an underlying H tone, the result is as one would expect from a word with a single of either of these tones. For instance the root *puput* has a high tone, as we can see in (68-a-d), since we saw in (65) that these object prefixes do not contribute a tone, so these tones must come from the root. But we also saw in (65) that the *u-* and *a-* object prefixes do contribute a tone, and yet the surface tonal shape of the word is unchanged.

(68)

a. ku-pupŭt-â 'to beat'

b. ku-ni-pupŭt-â 'to beat me'

c. ku-ku-pupŭt-â 'to beat you sg.'

d. ku-mu-pupŭt-â 'to beat him/her'

e. ku-u-pupŭt-â 'to beat us'

f. ku-a-pupŭt-â 'to beat you pl./them'

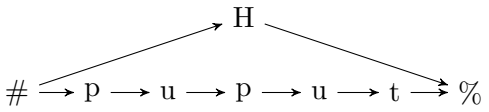
A way we can conceive of what is going on for the sake of the discussion is that the tone contributed by the prefix is 'redundant': it will surface when it is alone in the form, but when added onto a graph that already contains a H tone it will not add to it.

This follows from the way the object affix has been specified in (66) and from how H

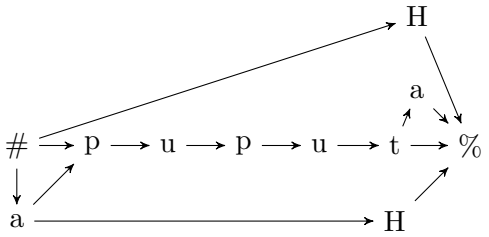
[7]This assumes that the suffix *-a* is already there at this point in the derivation, which is both preferable here for for illustration purposes and also argued to be the general Bantu structure by Hyman (2009), Inkelas and Downing (2015), and multiple previous work by Downing. But the analysis presented here is not affected if *-a* is inserted late in the derivation

roots are encoded in (59). The root $\sqrt{puput}$ is as in (69). Once affixed with the verbal suffix and the object prefix, there is a step in the derivation where the form looks like (70). In this picture, the H on top of the image is the one contributed by the root. The one at the bottom is the one contributed by the object prefix. We can see that they run parallel to each other, which given the assumptions so far implies pronouncing them at the same time. Reasonably, since they are the excact same feature, for the segments that are parallel to both this is identical to having a single H tone in the form, hence we derive that multiple H tones would have a 'redundant' behavior. And since both H's precede the end of the word, they will be equally targeted by the late process narrowing down the H tone to the end of the word.

(69) $\sqrt{puput}$



(70) 2pl.obj+$\sqrt{puput}$+mood



There are other sources of H tones in Digo verbs. An important one is subject prefixes, which appear outside of the tense prefix.

(71) Digo indicative verbal template

SUBJ.-TENSE-(OBJ.)-ROOT-a

(72)

a. ni-na-tsukur-a 'I am taking'

b. ni-na-mu-tsukur-a 'I am taking him/her'

c. a-na-tsukŭr-â 'he/she is taking'

d. a-na-mu-tsukŭr-â 'he/she is taking him/her'

As we can see in (72), $\sqrt{tsukur}$ is a toneless root and the singular third person subject prefix *a-* (as well as the third person plural *ma-* as we will see in (74)) carries a high tone that is realized as the now familiar final pattern, just like the first and second plural person prefixes *u-* and *a-*. We can therefore anticipate the underlying form of the third person subject prefixes to contain a similar donating H tone. However an interesting behavior arises when these new prefixes are added to a form that already has a H. Consider (73) which completes the paradigm in (72).

(73)

e. ni-na-a-tsukŭr-â 'I am taking them'

f. a-na-á-tsúkúr-â 'he/she is taking them'

(74)

a. ni-na-pupŭt-â 'I am beating'

b. u-na-pupŭt-â 'you sg. am beating'

c. a-na-púpút-â 'he/she am beating'

d. tu-na-pupŭt-â 'we are beating'

e. mu-na-pupŭt-â 'you pl. are beating'

f. ma-na-púpút-â 'they are beating'

The form in (73-f) shows that when both the subject prefix and the object prefix contribute a tone, all vowels between the tense prefix and the final vowel surface as H. Similarly we know from (68) that $\sqrt{puput}$ has an underlying H that surfaces without any of the tone-bearing prefixes, but (74) shows that with one of the third person prefixes the form also surfaces with all vowels between the tense prefix and the final vowel as H. Note that it also

hides part of the final pattern, the final rising-falling sequence has lost its rising part as the rest of the form prior to it is now high.

The tense prefix *ka-* also behaves this way. (75) shows *ka-* on root we know to be toneless from (72) and (73). (76) shows what happens when *ka-* is prefixed to a root bearing a high tone.

(75)

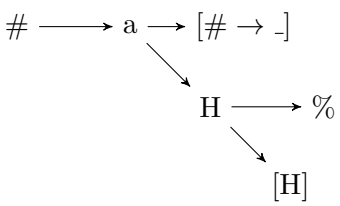
ni-ka-tsukŭr-â	'I have carried'
u-ka-tsukŭr-â	'you sg. have carried'

(76)

ku-kumbukĭr-â	'to remember'
ni-ka-kúmbúkír-â	'I have remembered'
u-ka-kúmbúkír-â	'you sg. have remembered'

This new tone is therefore clearly not 'redundant' in the way I labelled the behavior of the tone of the object prefix. The tone of this new prefix, to the contrary, supplements whatever tone the stem already carries. Let us call this tone 'supplementary'. We can characterize the behavior of this class of prefixes with 'supplementary' tones with underlying forms like the following.

(77) Digo 3rd.sg. subject

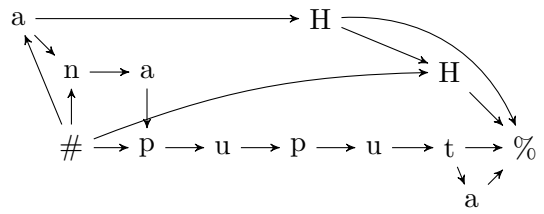


This form only minimally differs from (66) in that it has an additional sticky end that seeks H tones if there are any. The result of this is that for a stem without any H tone,

adding (77) will create the familiar pattern, but when added to a form that does contain a H of any origin, this new H has to precede it.

Consider the derivation of forms with a H tone from the root and one from a subject prefix as in (74)[c]. It starts with the root of $\sqrt{puput}$ as in (69) to which the tense and subject prefix are added, resulting in (78).

(78) 3s.subj+present+$\sqrt{puput}$+mood



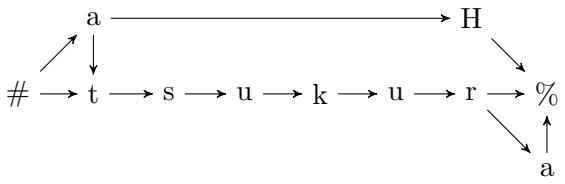
The graph in (78) crucially differs from (70) in that now the two H tones are not parallel anymore: the H introduced by the subject pronoun precedes the one from the root. As a result one H does not directly precede the end of the word. If the process restricting the pattern of tones to the end of the word is sensitive to this difference (e.g. targeting H that only precede % and nothing else) it follows that this H will not surface as one of the two final patterns, rising-falling or high-low, and it is expected that it will be realized on a greater portion of the word.

Simiarly the derivation of (73)[f] will start with the toneless root in (79), to which we add the 3p prefix as in (80), and the tense and subject prefixes as in (81). As in (78) we have a form where one of the H tone precedes the other, and hence will not be affected by the process restricting it to the end of the word.

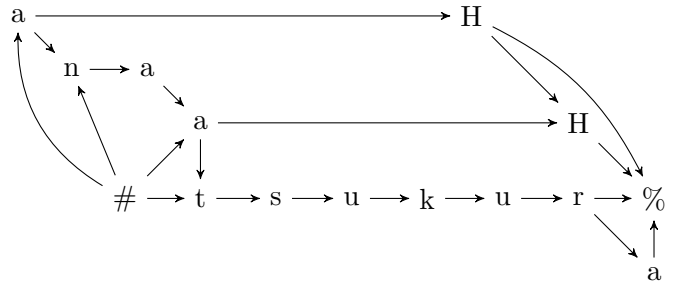
(79) $\sqrt{tsukur}$

→ t → s → u → k → u → r → %

(80) 3p.-$\sqrt{tsukur}$-a



(81) 3s-pres.-3p-$\sqrt{tsukur}$-a



The only thing missing from (78) and (81) is something to restrict the non-final H to after the tense prefix. This could be as simple as a phonological rule adding a precedence link from the tense prefix to the H tones of the word. A plausible way to obtain this is to assume that the object prefix is somewhat separated and in that the subject prefix, the root and the mood suffix form a natural unit syntactic unit. There could then be a silent morpheme added that the non-final H can target to add a precedence link. Kisseberth (p.129) does argue in favor of such a unit which he calls the verbal complex. In any case this would manifest itself here as a precedence link from the tense affix 9or something near it) to the tone added at some point in the derivation. I will not dwell into this aspect of the Digo tonology.

More interesting is the right-hand boundary of the 'supplementary' tone. Although the forms in (73) and (74) suggest that the 'supplementary' tone extends over the whole verbal complex, the data in (82) shows that it is more complicated than this. Crucially the tone does not extend to the right of voiced obstruents. To see this in (82-b), recall that in forms above like (74) the 'supplementary' tone spreads to the penultimate vowel and hides the

rising part of the rising-falling final pattern, which does not happen in (82).

(82)

a.	a-na-gurǐr-â	'he/she is buying for'
	a-na-á-gurǐr-â	"he/she is buying for them'
	a-na-demurǐr-â	'he/she is scolding'
	a-na-á-demurǐr-â	'he/she is scolding them'
b.	a-ka-ézěk-â	'he/she has thatched'
	a-ka-wézěk-â	'he/she has enabled'
	a-ka-súrúbǐk-â	'he/she is strong/firm'
	a-ka-ú-tógŏr-â	'he/she has praised us'

There is a very natural way to describe what is going on here: the 'supplementary' tone of the tense *ka-* and the subject prefixes *a-* and *ma-* must precede voiced obstruents. The tricky part is that is that this seems to be true only when this tone is 'supplementing' another, not when it is the only tone of the word. E.g. in (83) the tone causes the regular final pattern despite it following a voiced obstruent.

(83)

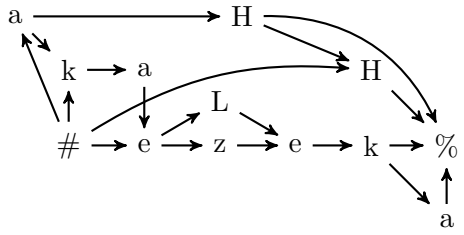
ku-togor-a	'to praise'
ni-na-togor-a	'I am praising'
u-na-togor-a	'you sg. are praising'
a-na-togŏr-â	'he/she is praising'
ma-na-togŏr-â	'they are praising'

Given the assumption above that voiced obstruents have a L tone I propose that a phonological process like (84) is responsible for this, which adds a precedence link from an H to voiced obstruents if this H precedes another. Thus the form built in (85-a), similar to the form in (78), undergoes this process to give (85-b), with its 'supplementary' H restricted

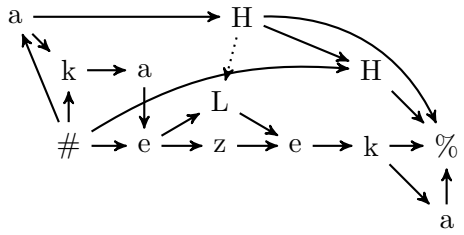
to precede /z/, or more accurately .

(84) If an H precedes an H, make the former also precede all L's in the form.

(85) a.



b.



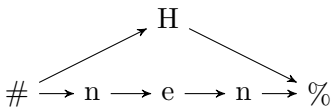
Consider now the exceptional behavior of some monosyllabic roots. Kisseberth notes that unlike polysyllables for which there are two behaviors, captured so far by positing H roots and underspecified roots, there are three behaviors for monosyllables, whose difference is visible when comparing the infinitive to the extended form. There are monosyllabic roots with the regular unspecified pattern as in (86-a), roots with the regular H tone pattern as in (86-b), and roots that are low-toned in isolation, but show the H tone pattern when the extension is present as in (86-c).

(86) Digo monosyllabic verbal roots

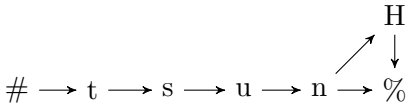
a.	ku-rim-a	ku-rimir-a	'to cultivate'/'to cultivate for'
b.	ku-nĕn-â	ku-nenĭrâ	'to speak'/'to speak for'
c.	ku-tsun-a	ku-tsunĭrâ	'to skin'/'to skin for/with'

One way to deal with this is to treat these cases as an instance of tone donation as KiYaka in the previous section, except here roots are donating. So while the regularly-behaving monosyllable roots have the form in (87), the roots whose H tone only appears on suffixes have a form like (88).

(87)

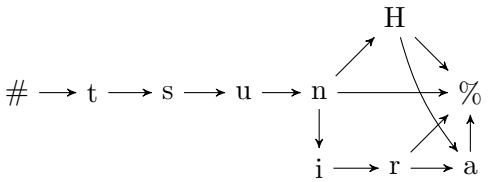


(88)



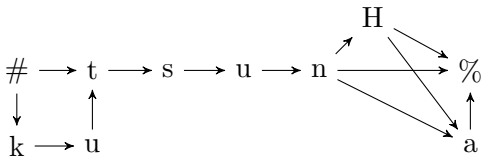
These forms, once suffixed with the extension *-ir* and the verbal suffix -a will surface with the expected final pattern

(89)



But without an extension the form will end up looking like (90). Given the reasonable assumption that H cannot be pronounced without being parallel to some vowel or consonant, the tone of a form like (90) will not be able to surface phonetically, since H must follow /n/ but precede /a/.

(90)



And this concludes the analysis of Digo verbal tonology. We see that given PROP assumptions it is possible to make sense of complicated tone patterns like those of Digo. The analysis involves root which may contain an H from # to % or not, as well as donator prefixes. These donator prefixes are of one of two kinds, adding either a tone in parallel

to tones already in the form, or adding them preceding other tones, giving rise to the 'redundant' and 'supplementary' patterns of behavior.

We can only truly see the benefits of this analysis if we compare it to previous ones. We will therefore turn to the analysis of Kisseberth (1984).

3.3.4 Digo in Kisseberth (1984)

Kisseberth already offered an analysis of Digo in Autosegmental Phonology. We will very quickly go over it to highlight the differences from PROP.

First, Kisseberth assumes that all tones on verb come floating and he posits a High Tone Deletion rule deleting one H tone in what he defines as the verbal complex, comprised of the root and subject prefixes, when there are two H tones. This accounts for what I have called the 'redundant' vs. 'supplementary' behaviors: this rule neutralizes all the cases where there is only one H tone on the root, one H tone on the object prefix, or both. As a result a H tone on an object prefix does not add anything when there is already one on the root. All these three types of forms as well as forms with only one H tone from a subject prefix all neutralize after High Tone Displacement which attaches the rightmost floating H to the Rightmost tone-bearing vowel as exemplified in (92).

(91) High Tone Deletion (copied from Kisseberth 1984, p.130)

Verbal Complex [H 1 H 2] → 1 Ø

(92)

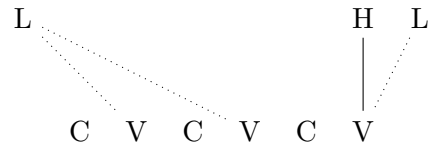
Input	H ku- puput -a	H ku- a- fwinik -a	H H ku- a- puputa -a	H a- na- tsukur -a
High tone Deletion	H ku- puput -a	H ku- a- fwinik -a	H ku- a- puputa -a	H a- na- tsukur -a
High Tone Displacement	H ku- puput -a	H ku- a- fwinik -a	H ku- a- puputa -a	H a- na- tsukur -a

From these forms Kisseberth derives the two forms of the final pattern, which for a reminder are High-Low when the final consonant is an obstruent and Rising-Falling otherwise. Starting from the forms above, Kisseberth posits first that there are boundary L tones around the verb as in (93-a). At this point in the derivation these L tones spread inward to all toneless vowels, and to at least one even if it is already high, yielding (93-b). Then there is a rule of Leftward High Spread which spreads H one vowel to the left as in (93-c).

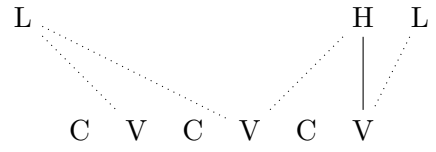
(93)

a.

b.



c.

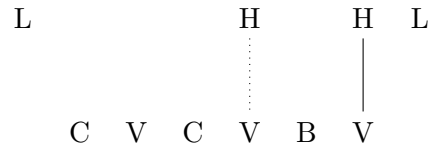


We now have in (93-c) a Rising-Falling pair of syllables. This derives the most common form of the final pattern. As for forms with a voiced obstruents, Kisseberth posits a rule of High Tone Doubling beforehand which adds a new H tone when a final High toned vowel is preceded by a voiced obstruent as in (94-a) where B stands for any voiced obstruent. Then the spreading of the L boundary tones yields (94-b), and finally a rule of Final Fall Simplification delinks a H tone from a final HL syllable if this H is not also attached to

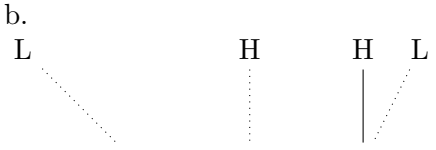
another vowel. This yields the High-Low version of the final pattern.

(94)

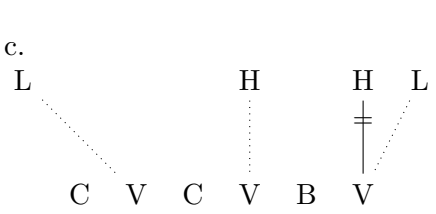
a.



b.



c.



And finally the blocking effect of voiced obstruents when a second H tone spreads is attributed to a Low Tone Insertion rule that gives a L tone to voiced obstruent, thus blocking the spread.

This is a very straightforward and interesting analysis. There is however one thing to note with which the PROP analysis I offered contrasts: all of Kisseberth's rules above need to apply only to verbs. Nouns do not undergo tone displacement or spread in the same way. Kisseberth needs a theory in which phonological rules can be indexed for the syntactic environment in which they take place, and directly refer to morphosyntactic structure like the High Tone Deletion rule which refers to the verbal complex. This is obviously a problem if the goal is a modular theory of phonology.

PROP in contrast manages to encapsulate all this to the phonology by putting all the information distinguishing the behavior of different tones within the vocabulary items. This is an indispensable quality if one believes in a fully modular theory in which the phonology cannot reference the syntax.

This is made possible in PROP because of the increased representational freedom. There

are more ways to put information into the representation and as such it is possible to attrubute the behaviors observed not to the syntactic context but the lexical items involved.

3.4 Summing up

The analyses in this paper brought us to recast a number of basic patterns and discover a number of principles. The account of parallel features developed here re-conceptualizes vowel harmony as a representational phenomenon involving features whose lexical entries make them span multiple segments. We also now have the simple but powerfully general nesting principle according to which competition among segments with incompatible features will be won by the 'inner' one, which we saw at work as an explanation of both transparent and opaque segments, and which we can hope to derive from more basic principles of motor planning organization. We have a superior understanding of donator morphemes now that the representation allows features to be simultaneously independent and ordered with regard to each others, while autosegmental phonology allows only one or the other. And finally we have a novel understanding of Bantu depressor consonants that carry low tones and of how they may effect the phenomena we observe.

The suggestion of treating suprasegmental material as phonological material that is simultaneous to the segmental material is suprisingly classical. It was the motivation for Hockett's 1954 coining of the term *simulfix* to convey the relation of intonational contours to segmental material. And even before that Harris (1944) suggested to account for various phenomena of phonology by breaking traditional segments and phonemes into simultaneous components.

We will return to more tone phenomena as we discuss the interaction of parallel structures with reduplication in chapter 7.

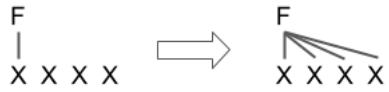
3.5 PROP compared to its alternatives

It would be worthwhile to contrast the PROP analysis of long-distance phonological phenomena developped in this chapter with its two main contenders: Autosegmental phonology and Search-and-Copy. We have already seen a bit of the first comparison above in section

3.3.4 with regard to Kisseberth's analysis of Digo, but more generally there are more constrasts to be made between PROP and its competitors.

In Autosegmental Phonology (Leben (1973), Goldsmith (1976)) vowel harmony and tonal phenomena require an operation of spreading as in (95), which actively spreads the association of a feature onto other segments. In a search-and-copy, vowel harmony requires actively copying features from one segment to another as in the procedure taken from Nevins (2010) in (96). Both of these analyses have some things in common.

(95)



(96) *Harmonic Search-and-Copy procedure, in two steps: (τ, δ, F)*

a. Find: x = the closest τ to the recipient y in the direction δ

b. Copy: the value of F on x onto y, where x, y are segments, F is a feature, τ is a predicate over segments.

First they treat both harmony and tone spreading as the outcome of a process. Languages must have a rule causing segments to either spread or copy features at a distance. In contrast the PROP analysis in terms of parallelism presented here is representational and passive. PROP attributes harmony to the representation and therefore to the static details of vocabulary items and how they arrange themselves in word-formation. This is interesting as it means that PROP maximizes the use of representation in the explanation, as opposed to the existing approaches in terms of processes.

A second, more important difference is that PROP is unique in deriving harmony and tone spreading directly from the fundamental elements of phonology. In PROP, there is no extra stipulation granting to phonology the power to spread or copy features; here it is a direct and unavoidable fact of phonology that the representation is free enough to allow them. In Autosegmental Phonology and Search-and-copy, one can ask why it is that phonology allows long-distance spreading or copying in the first place. It is a mystery why phonology allows those things. Those possiblities feel tacked onto a system that could easily exist without allowing long-distance phenomena. But in PROP, harmony derives from the

most basic ingredients of phonology: features and precedence left free to be organized in any way. In PROP, forbidding vowel harmony would require extra stipulations, and not the other way around. This, I think, is the most interesting aspect of PROP for harmony and word tone.

It is worth noting at this point that there is a precedent in trying to incorporate Search-and-copy with a Multiprecedence representation in the dissertation of David Shen (Shen, 2016). Unfortunately Shen does not discuss in depth how the complex structures of Multiprecedence would interact with Search-and-Copy. The thesis uses Search-and-copy to handle sticky ends such that they can start from the edge of a stem and search left or right for their attachment point, and then it discusses Search-and-copy vowel harmony without any further reference to the representation. Multiprecedence and harmony are disconnected topics of the dissertation with no overlap. Shen does not discuss the interesting issues that would arise when using Search-and-Copy for vowel harmony in a Multiprecedence context, e.g. search going in one direction and encountering a branching, or search being stuck in a loop, or search starting from one segment, going along a loop, and finding itself. There is therefore little to compare between Shen's multiprecedence-friendly approach to harmony and PROP beyond what I already said about Search-and-Copy in general.

Chapter 4

Affix position and Reduplicative size

Although not the primary focus of Raimy (2000), the multiprecedence proposal shows that Multiprecedence can account for infixation in a satisfactory way.

> The new representations proposed [...] have major implications for the understanding of what the phonological aspects of morphemes are and how morphemes are concatenated. The notions of root, prefix, suffix, infix, etc. can be directly encoded in the phonological material that is associated with a morpho-syntactic feature. (Raimy, 2000, p.66)

The sticky-end, as an apparatus designed to select an attachment point, is ideally suited to encode information about the precise locus of attachment of a morpheme, including within a stem. The analysis captures two important theoretical goals. First the notion that there are genuine infixes in the sense of Blevins (1999) and Yu (2003), meaning they are not derived from inherent prefixes or suffixes and displaced by the phonology, and second the notion that infixes are just a regular type of affix, without any special processes of their own. In Multiprecedence an infix is like any other affix, except its sticky-ends happen to target other things than the edges of the word. For example the Atayal Animate Actor focus in (1) can be represented with the following infix attaching between the initial segment and

the segment following the initial segment.

(1) Atayal Animate Actor Focus (from Yu 2007, p.75)

root	AAF	gloss
qul	q**m**ul	'snatch'
kat	k**m**at	'bite'
hŋuʔ	h**m**ŋuʔ	'soack'

(2) Atayal Animate Actor focus infix

$$[\# \rightarrow \_] \longrightarrow \text{m} \rightarrow \big[[\# \rightarrow \_] \rightarrow \_\big]$$

PROP inherits all of those insights of Multiprecedence, but with even more freedom to analyse other phenomena relating to the position and size of affixes, which we will cover in this chapter.

4.1 Affix position in Tamazight Berber

Svenonius and Bye (2011, p.40) describe the data of Tamazight Berber in (3). While most singular and gender agreement markers are prefixes, the first singular is a a suffix /-ɣ/, and while most plural agreement markers are suffixes, the first plural is a prefix /n-/.

(3)

	Sg.	Pl	
1	ʕum-ɣ	n-ʕum	'I swam'; 'we swam'
3m	i-ʕum	ʕum-n	'he swam'; 'they swam'.

This is a problem for most models of morphology in which the linear order of morphemes is decided prior to vocabulary insertion, and hence a consistent order among morphemes of the same paradigm is expected. But this is unremarkable in PROP, because linear order is *not* presumed to be fixed prior to vocabulary insertion, rather it is the underlying form

of the vocabulary item that encodes its position in the form of sticky-ends, morpheme by morpheme. The four affixes in (3) are simply the following:

(4) 1.sg. affix

$[\_ \rightarrow \%] \longrightarrow \gamma \rightarrow \%$

(5) 3m.sg. affix

$\# \rightarrow \mathrm{i} \longrightarrow [\# \rightarrow \_]$

(6) 1.pl. affix

$\# \rightarrow \mathrm{n} \longrightarrow [\# \rightarrow \_]$

(7) 3m.pl affix

$[\_ \rightarrow \%] \longrightarrow \mathrm{n} \rightarrow \%$

In this respect the PROP analysis is in the spirit of the analysis of Svenonius and Bye (2011). They also interpret this pattern with information within the UR, hence it would be useful to compare the aspects of Svenonius and Bye's proposal to PROP.

Their core proposal is a novel phonological machinery they call antitropal affixes. They posit a new phonological symbol $\nsim$ that seeks non-alignment with a boundary, coupled with a constraint IDENT[antitropal] that penalizes morphemes aligned with said boundary. They propose the following vocabulary items and constraint ranking for Berber,

(8) Tamazight 3m.sg. agreement (Svenonius and Bye, 2011)

$\mathrm{i} \nsim]_{\omega} < v, \pi >$

(9) Tamazight 1pl agreement (Svenonius and Bye, 2011)

$\mathrm{n} \nsim]_{\omega} < v, \pi, Participant, Author, Pl >$

(10) n-ʕum 'we swam (Svenonius and Bye, 2011)

	$ʕ_1u_2m_3$+[$_\omega$ $n_x \nsim$]$_\omega$	IDENT[antitropal]	O-CONTIGUITY	LINEARITY
a.	[$ʕ_1u_2m_3n_x$]$_\omega$	*!		
b.	[$ʕ_1u_2n_xm_3$]$_\omega$		*!	$\succ$ 1 2 3 x *
c. ☞	[$n_xʕ_1u_2m_3$]$_\omega$			$\succ$ 1 2 3 x * * *

Antitropality is more generally the core of Svenonius and Bye's theory of morpheme placement. It can lead to morepheme position reversal in Berber, but with CONTIGUITY lower ranked it also leads to infixation. In Svenonius and Bye's system therefore there are two forces involved in morpheme order: the order given by the syntax, and the order emerging from the ranking of ANTITROPAL with regard to other constraints for morphemes containing $\nsim$.

While I agree with the move of putting affix order in the UR, it goes without saying that the redundancy of Svenonius and Bye's system can easily be avoided by rejecting that any order is imposed by the syntax. If URs can contain information pertaining to their position, we might as well go all the way and let that be the only determinant of position. This is accomplished in PROP with the use of sticky-ends as the only machinery responsible for ordering the segments of a morpheme with regard to another[1].

It is interesting that $\nsim$ is defined negatively as non-alignment. Presumably the reasoning is to have a mechanism that does the minimum they need, namely only ban complete prefixhood or complete suffixhood, to let the position be otherwise derived from the con-

[1]A consequence of this is that there is no principle of the grammar in PROP enforcing paradigmatic uniformity in affix order. If a language has e.g. multiple case suffixes, it must be individually specified for every case affix that it is a suffix and there is nothing in the grammar preventing a language from having a mix of prefixes, suffixes, and infixes as case markers. I do not see it as a major problem for two reasons. First there are cases of non-uniformity in affix order across paradigms. We saw the Tamazight Berber person affixes in which the. Other examples abound. In the system of class affixes of Tiv, most classes are marked with prefixes, except two that are marked with suffixes and three with circumfixes (Welmers, 2018, p.205-207). De Wolf (2017, p.180) lists six other Benue-Congo languages with a mix of prefixes and suffixes in their class marker system: Kom, Mam, Ukel, Duk, Dak, and Kag. Another example is the person markers of multiple Muskogean languages in which the first person agent market is a prefix but all other persons are suffixes; Cysouw (2003, p.11) lists Chickasaw, Alabama, Koasati, and Choctaw as having this pattern. Cysouw also lists two Tequistlatequan languages with the same pattern of first person prefixes and suffixes for other persons: Highland Chontal and Huameltultec. Yet another example is from Kilmeri in Foley (2017, p.394) in which the modality system is mostly comprised of suffixes except for one prefix and one circumfix.

Given that the possibility of non-uniform affix order must definitely be allowed in the grammar, i see no reason to try to make affix ordering uniformity a deep property of grammar. The tendency toward uniformity may simply boil down to diachrony (e.g. the similar historical origin of similar affixes).

straint ranking, a natural OT move. However cross-linguistic surveys of infixation such as Yu (2003) have showed that Prosodic Optimization does not account well for the data of infixation, and it is more fruitfully analyzed in terms of affixes seeking a specific pivot in the word. With this in mind we could easily modify Svenonius and Bye's proposal by inventing a new symbol, say $\sim$, which positively seeks a certain attachment point. Infixation in Atayal described in the previous section could be handled as (11) where the affix seeks contiguity with a certain consonant, and infixation in Tagalog described in chapter 2 could be handled as (12) where the affix seeks contiguity with a vowel.

(11) Positively-defined Atayal Animate Actor Focus infix inspired by Svenonius and Bye (2011)
/m $\sim$ C_2/

(12) Positively-defined Tagalog *um*-infixation inspired by Svenonius and Bye (2011)
/um $\sim$ V_1/

And with such a machinery needed for infixes, we also get prefixation and suffixation for free:

(13) Positively-defined prefix *un-* inspired by Svenonius and Bye (2011)
/ʌn $\sim$ X_1/

(14) Positively-defined suffix *-able* inspired by Svenonius and Bye (2011)
/X_l*ast* $\sim$əbl/

At this point it is obvious that we have essentially re-invented the sticky-end mechanism through a different notation, by re-imagining the system of Svenonius and Bye (2011) stated positively. The sticky-end-centric approach to affix position suggested here is not radical, it simply involves taking ideas that are already around and pushing them to their logical limit. In a sense, we can even compare the sticky-end system to the informal descriptive notation of affixes with hyphens: at its core [# $\rightarrow$ _] is merely a formalization of the hyphen in a prefix notated as /ʌn-/.

This should be interesting to all. With this kind of machinery one can offer accounts in the lines of Svenonius and Bye (2011) without having to postulate a syntax-given order at all. If a machinery is powerful enough to place a morpheme after the first segment', it shouldn't be very difficult for it to place one before the first segment. Once we have accepted that the UR of a vocabulary item can contribute to its position, which seems to be needed for infixes according to Svenonius and Bye (2011), postulating a pre-vocabulary-insertion order is redundant.

Using sticky-ends in the phonology is a matter of taking seriously the idea that morphemes have phonologically-defined requirements as to their position and operationalizing it. Svenonius and Bye (2011) did so to a degree with $\nsim$, and in this chapter we will discuss how to go even further with sticky-ends.

4.2 Circumfixation in Georgian and Amatlan Zapotec

One peculiarity of affixation in PROP is the capacity to represent circumfixes *qua* circumfixes. The notion of circumfixes has long been challenged, in part because it does not fit with the so-called concatenative ideal in the sense of Svenonius and Bye (2011), but some strong cases of circumfixation whose two parts do not occur independently are mentioned in Hall (2000, p.542): the Georgian comparative/superlative *u-...-esi*, e.g. *lamazi*, 'beautiful', *u-lamaz-esi* 'more/most beautiful', and the Amatlan Zapotec negative *na-...-t*, e.g. *top* 'to gather', *na-top-t* 'to not gather'. These can be respectively handled in PROP with the following affixes:

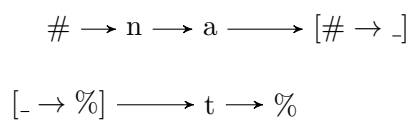
(15) Georgian comparative/superlative affix[2]

$$\# \longrightarrow \mathrm{u} \longrightarrow [\# \rightarrow \_]$$

$$[\_ \rightarrow \%] \longrightarrow \mathrm{e} \longrightarrow \mathrm{s} \longrightarrow \mathrm{i} \longrightarrow \%$$

[2]Note that this affix and the following one form a disconnected graph. PROP needs not make any assumption about the connectiveness of URs.

(16) Amatlan Zapotec negative affix



Models of word-formation in which morpheme order is settled prior to vocabulary-insertion struggle with circumfixes, as they have to assume that every affix is inherently a prefix or a suffix. This has led to analyses in which circumfixes do not exist and all apparent cases involve two morphemes, a prefix and a suffix independently found in the language (e.g. Corbin 1987), but as argued e.g. by Anderson (2015) this is less convincing for cases like the above where the initial and final part are not affixes independently found in the language, raising the question of how the grammar conspires to force them to coocur. By dissociating affix position from insersion PROP has no such limitation and does not need to make ad hoc assumptions about attested word-formation processes that look like circumfixation.

This is possible in PROP because there is no requirement for a directed graph to be connected. Here I have postulated disconnected graphs as the underlying forms of the circumfixes of Georgian and Amatlan Zapotec. Disconnected graphs also readily account for affixes comprised of an infixed part and either a suffixed or prefixed part (sometimes called transfixes, parafixes, or polyaffixes) attested e.g. in Blevins' 1999 account of Leti. This is yet another possibility that follows freely from the geometric possibilities of PROP that would take extra stipulations to forbid from the theory.

4.3 Variable-position affixes in Afar

Fulmer (1997) discusses the variable position affixes in Afar. A number of Afar verbal affixes can surface either as a prefix or as a suffix to the root depending on whether the root is vowel- or consonant-initial. Words starting in *a-* behave as consonant-initial. The suffixes

-$\bar{e}$ amd -$\bar{a}$ are aspect markers[3].

(17) Afar conjugation examples

1s		2s		3sf	
ab-ē	*do*	ab-**t**-ē	*do*	ab-**t**-ē	*do*
kal-ē	*prevent*	kal-**t**-ē	*prevent*	kal-**t**-ē	*prevent*
robaaq-ē	*bounce(tr.)*	sug-**t**-ē	*had*	sug-**t**-ē	*had*
ekk-ē	*become*	**t**-ekk-ē	*become*	**t**-ekk-ē	*do*
ookom-ē	*win*	**t**-ookom-ē	*win*	**t**-ookom-ē	*win*
3sm		1p			
ab-ē	*do*	ab-**n**-ē	*do*		
be-ē	*take*	giin-**n**-ē	*pull*		
kallax-ē	*beg*	fan-**n**-ē	*want*		
y-erd-ē	*run*	**n**-ekk-ē	*become*		
y-oogoq-ē	*bury*	**n**-ookom-ē	*win*		
2p		3p			
ab-**t**-ē-**n**ī	*do*	ab-ā-**n**ā	*they did*		
mak-**t**-ē-**n**ī	*turn*	sool-ē-**n**ī	*stand*		
nak-**t**-ē-**n**ī	*drink milk*	nak-ē-**n**ī	*drink milk*		
t-ekk-ē-**n**ī	*become*	**y**-okm-ē-**n**ī	*eat*		
t-ookom-ē-**n**ī	*win*	**y**-ookom-ē-**n**ī	*win*		

In short, Afar has a 2nd person /t/, a (homophonous) 3rd feminine /t/, a 3rd masculine /j/, and a plural /n/ (I will ignore the vowel, as it seems to be epenthetic and agree with the preceding one and could be inserted later in the derivation). The immediately obvious generalization of their location is that they are prefixed to vowel-initial roots and suffixed consonant-initial (and [a]-initial) roots, with two caveats: i) /n/ gets 'second choice', and

[3]Unfortunately although Fulner provides a lot of examples, because she is working with data from other source she provides no complete paradigm that would allow for convenient comparison across the same verbs in a single table, hence the format in multiple lists of representative examples summarizing the 14 lists in Fulmer (1997, p.137-146)

if the initial position is occupied by one of the other affixes it behaves as if affixed to a C-initial root, and ii) /j/ does not surface when one would expect it to be suffixed.

A less obvious detail is that there are two positions for post-posed affixes: one between the root and the aspect marker, and one after the aspect marker. The generalization being that /n/ occupies the latter position only when another marker is present (either prefixed or in the earlier suffix-side position between the root and the aspect marker).

This can be accounted for in PROP as a parafix in the sense of chapter 3, this time a parafix containing all the features of the relevant segment, except a +consonant feature (which for brevity I will notate /t$_{\emptyset C}$/). a full segment. I will assume that such a segment cannot surface unless it is parallel to some +consonantal feature, an assumption reminiscent of the autosegmental notion that floating segments un-associated to a CV tier do not surface. This segment can only surface simultaneously to another segment with which it does not conflict.

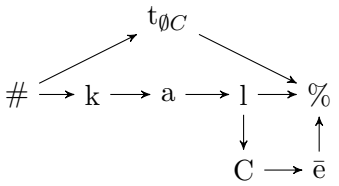
Combined with the plausible assumption that the V-initial forms, as well as the -$\bar{e}$ suffix start with (the PROP equivalent of) an empty C-slot, we can derive the first generalization above from the structures involved. The 2s affix will be a parafix as in (18).

(18) Afar 2s affix

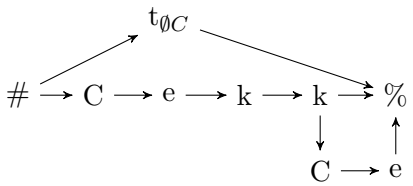
$\# \rightarrow t_{\emptyset C} \rightarrow \%$

When added to a consonant-initial form as in (19), the only location where the /t/ can surface is with the {C} of the aspect suffix /C$\bar{e}$/ with which it does not conflict in any feature. However when added to a V-initial form as in (20) there is also a {C} location at the beginning of the form.

(19) *kal-**t**-$\bar{e}$*



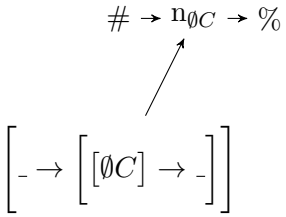
(20) *t-ekk-ē*



This cannot be the full story, as something needs to be responsible for forcing /t/ into the first {C} of rather than the second or both. Potentially it is simply a matter of positing a phonological rule to the effect that /t/ precedes all {C}'s that are transitively preceded by another {C}; alternatively some phonetic principle, universal or language-specific, forces this graph to be realized such that /t/ is 'discharged' as early in the form as it can be. Since the above is sufficient to handle the contrastive possibilities of Afar I contend that the exact issue of the realization of these graphs is not an issue of PROP, but of phonetic implementation.

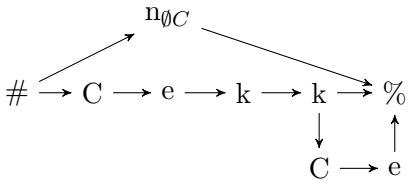
The behavior of the plural /n/ is more complex. The first plural forms show that, like /t/, /n/ can occupy either or both of these {C} positions when there is no other affix to take it first, and the position of /t/ in the C-intial second plural shows that this second {C} position is present in these forms, yet in V-initial second plurals the /n/ does not occupy the seemingly free second position, occupying a third position after the aspect marker. This can be accomplished if /n/ is set in parallel to the whole form just like /t/, but must also be ordered with regard to /t/ or /j/, or ordered with regard to something ordered with regard to /t/ or /j/.

(21) Afar plural

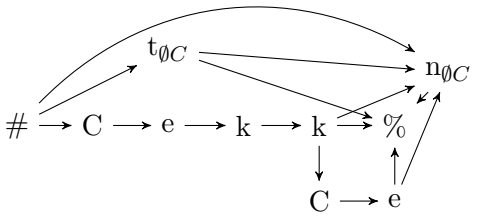


This new sticky-end seeks a segment with the property of following a segment with the property of preceding a segment with the property of being unspecified for Consonant[4]. When attached to a form without another affix it will behave as in (22), namely just like /t/ in (20). But when there is another affix, it will also follow anything that precedes anything that follow that affix. In (23), since the only thing that follows /t/ is %, /n/ will follow everything that precedes %, in this case /k/, /ē/, as well as /t/ itself, hence it will surface as a suffix. If the epenthesis applies at this point whenever /n/ has not found a {C}, we derive the correct form.

(22) ***n***-*ekk*-*ē*



(23) ***t***-*ekk*-*ē*-***nī***



There are some exceptions to this pattern: vowel-initial words that behave as consonant-initial and take the suffixed forms, e.g. *in-'t-e* 'say-you-PERFECTIVE' and *iman-s-it-t-aa-'na* 'believe-CAUSATIVE-BENEFACTIVE-you-IMPERFECT-PLURAL' (Marušič, 2003, p.6). These forms as well as the /a/ forms have been argued to be a counterargument against the tempting analysis of this pattern in terms of syllable optimization, with the forms appearing as prefixes whenever doing so gives an onset to an otherwise onsetless syllable (Paster, 2009b,a). I agree with this assessment; there is no optimization in the PROP analysis

[4]Sensitivity to underspecification is a strong mechanics, but it is inessential to the analysis here and only used for convenience. Anything that can identify the conjugation affixes will do, be it a lexical diacritic or something else.

above. And as for the exceptional vowel-initial behaving as consonant-initial, these forms can simply be stored without the initial empty-C; it is a fact one has to know about a form in order to speak Afar. This would also account for /a/-initial forms

4.4 Unpredictable Infixation

This kind of arbitrariness is also found in various Siouan languages in which verbs unpredictably take prefixes or infixes. Albright (2000) observes that in Lakhota, "the position of subject marking is to a certain extent unpredictable, and must be listed on a verb-by-verb basis". Conside the examples of the first person (-)*wa*- in (24).

(24)

3rd person	1st person	gloss
lówan	wa-lówan	'sing'
núwe	wa-núwe	'swim'
káge	wa- káge	'do/make'
únpa	wa-'únpa	'lie down'
óta	wa-óta	'be many'
máni	má-wa-ni	'walk'
aphé	a-wá-phe	'hit'
hoxpé	ho-wá-xpe	'cough'
ixá	i-wá-xa	'smile'
ómna	ó-wa-mna	'smell'

As discussed by Rankin et al. (2003); Helmbrecht and Lehmann (2008a) there is a diachronic generalization here, namely the infixing behavior come from reanalysis of prefix+verb sequences as unanalysable roots, trapping some previous prefixes and forcing them to be reanalyzed a prefixes, a common diachronic scenario in the evolution of infixes according to Yu (2003, ch.4). But synchronically these are unpredictable and Albright argues that infixing can apply to novel forms.

As argued for the related Siouan language Hoček in Helmbrecht and Lehmann (2008b) these affixes challenge our theories of infixation, which hold that the location of infixes is phonologically defined. It was one of the main findings of Yu (2003) that all infixation could be accounted for as set right before or right after a specific phonologically-defined position in the stem such as 'first segment', or 'stressed vowel'.

Something has got to give, and somehow this arbitrariness must be handled somewhere. One solution would be to propose massive homophony between a prefix and one or more infixes, each specified both for a phonologically-defined position and for the set of roots to which it applies. The alternative –simpler in my opinion– is to accept that the phonological form of these roots contain some arbitrary diacritic which lacks a phonetic correlate but is of the phonological type and can serve as a target for the location of affixes.

This can be done in PROP by assigning each verb a feature on one of its segments as in (25), this feature will be the target of the infix in (26), placing itself between the [F]

segment and the segment preceding it, as in (27)

(25) $\sqrt{nuwe}$, $\sqrt{mani}$

$\# \rightarrow \mathrm{n}_{\mathcal{F}} \rightarrow \mathrm{u} \longrightarrow \mathrm{w} \longrightarrow \mathrm{e} \longrightarrow \%$

$\# \rightarrow \mathrm{m} \longrightarrow \mathrm{a} \rightarrow \mathrm{n}_{\mathcal{F}} \longrightarrow \mathrm{i} \longrightarrow \%$

(26) Lakhota 1st person affix

$[\_ \rightarrow [+F]] \longrightarrow \mathrm{w} \longrightarrow \mathrm{a} \longrightarrow [+\mathrm{F}]$

(27) *wa-nume*, *ma-wa-ni*

$$\begin{array}{l} \mathrm{w} \longrightarrow \mathrm{a} \\ \uparrow \quad \downarrow \\ \# \rightarrow \mathrm{n}_{\mathcal{F}} \rightarrow \mathrm{u} \longrightarrow \mathrm{w} \longrightarrow \mathrm{e} \longrightarrow \% \end{array}$$

$$\begin{array}{l} \qquad\quad \mathrm{w} \longrightarrow \mathrm{a} \\ \qquad\quad \uparrow \quad \downarrow \\ \# \rightarrow \mathrm{m} \longrightarrow \mathrm{a} \rightarrow \mathrm{n}_{\mathcal{F}} \longrightarrow \mathrm{i} \longrightarrow \% \end{array}$$

The nature of feature $\mathcal{F}$ here is inessential to the analysis as long as such a feature without direct phonetic correlate can be present in underlying forms and can be targeted by sticky-ends. All analyses of this pattern will have to resort to positing some difference between the URs of prefixing and suffixing affixes, or a morphological module containing a list of all prefixing and suffixing forms. PROP allows us to have an analysis of the former type without a special morphological module, in which a single form of the affix accounts for both the prefixing and infixing behavior.

4.5 Free variation of reduplicant location in Tagalog

Ryan (2010) describes the case of the Tagalog Contemplated aspect, which surfaces as CV-reduplication. In verbs with some sequences of one or more prefixes, it is claimed that the

reduplicant can freely vary in location. Ryan claims that Tagalog researchers are unanimous that this does not lead to semantic differences, and that native speakers produce all the different variants in speech (p.762). This cannot be a case of different syntactic orders with vacuous scope difference, because Ryan points out that in both examples below the Contemplated aspect scopes over the causative (p.763).

(28)

pà:-pa-buks-án ‘RED-CAUS-open-LOCATIVETOPIC’

pa-**bù:**-buks-án ‘CAUS-RED-open-LOCATIVETOPIC’

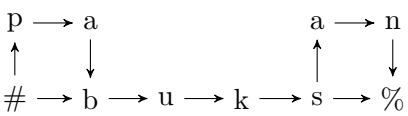
This can be accounted for in PROP if we assume the following: a sticky-end can intensionally describes a property that describes multiple segments of the stem it attaches to, but be specified to attach to a single one of them. I will represent this with a superscript U on the sticky-end. This can create ambiguity in attachment point, leading to this type of free variation. The Contemplated Aspect would have the underlying form in (29). The leftmost sticky-end seeks something that follow an initial segment and connects it to an initial segment.

(29) Tagalog Contemplated Aspect (preliminary version)

$$[[\# \rightarrow \_] \rightarrow \_]^U \rightarrow [\# \rightarrow \_]^U$$

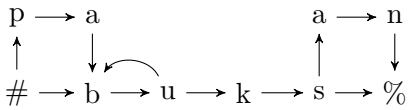
The result is that when attached onto a prefixed form like (30)[5], these sticky-ends have more than one initial segment to choose from, resulting in the two possible structures (31) and (32).

(30)

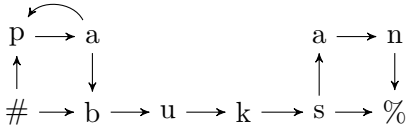


[5]Ryan (2010) confirms that the aspect scopes over the causative(p.763).

(31) *pa-**bu:**-buks-an*

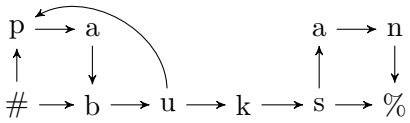


(32) ***pa:**-pa-buks-an*

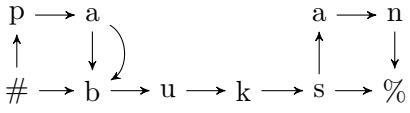


However this is insufficient. There are two segments that follow # and two segments following a segment that follow #, thus 4 possibilities. The following two graphs should be available if (35) is the actual form of the contemplated, because its two sticky ends can vary independently, yielding also the two graphs (33) with reduplication of both prefixes which is not cited as a grammatical alternative and (34) with a vacuous 'forward' link leading to no pronounciation change, which is not cited as able to carry Contempated reading.

(33) ****pabu:**-pa-buks-an*



(34) *pa-buks-an* (* with the intended Contemplated reading)



The essence of the problem here is that the sticky-ends as stated in (35) are independent, but need to be have a stated dependency: the sticky-end $[[\# \rightarrow \_] \rightarrow \_]^U$ cannot attach to just any segment following a segment that follows #, it must specifically attach to a segment of the stem that immediately follows the sticky-end $[\# \rightarrow \_]^U$.

I propose to accomplish this with features on the sticky-end itself that can be referenced by other sticky-ends. In (35) the sticky-end $[\# \rightarrow \_]^U$ finds a single segment following # and assigns it [F], and the sticky end $[[F] \rightarrow \_]^U$ finds the segment preceding [F] so that the morpheme as a whole adds a precedence link between the segment that follows [F] and segment [F]. This affix will only generate the forms (31) and (32) above.

(35) Tagalog Contemplated Aspect (final version)

$$[[F] \rightarrow \_]^U \longrightarrow [\# \rightarrow \_]^U_F$$

This capacity to add features via sticky-ends can be employed with regular features to derive cases in which morphemes affect the segments they attach to. For instance

4.6 Reduplicant size in Malagasy

Reduplication of variable size is attested in various languages. For instance Keenan and Polinsky (1998) and Hannahs (2004) describe the facts of Malagasy in which, for forms with ultimate or penultimate stress, the attenuative is formed by reduplication of the segments from the stressed syllable to the end of the word as in (36). This simply requires an affix as in (37) where [*] stands for a stressed segment. (37) adds a link from the last segment to the segment before the stressed vowel.

(36)

lèhibé	'big'	lèhibè-bé	'fairly big'
hadíno	'forget'	hadìno-díno	'forget a bit'

(37) Malagasy Attenuative (Penultimate or Antepunultimate stress)

$$[\_ \rightarrow \%] \longrightarrow \Big[\_ \rightarrow [*]\Big]$$

The situation is a bit more complex in the case of forms with antepuenultimate stress as in (38). Descriptively, C-initial forms appear as CVCV reduplication in which the second copy has a 'fortified' initial consonant; while V-initial forms appear as VCVC reduplication.

(38)

fá^{n}tat^{r}a	'known'	fà^{n}tapá^{n}tat^{r}a	'slightly known'
várot^{r}a	'selling'	vàrobárot^{r}a	'sort of selling'
áloka	'shade'	àlokáloka	'somewhat shady'
évot^{r}a	'bouncing back'	èvot^{r}évot^{r}a	'sort of bouncing back'

Although neither Keenan and Polinsky (1998) nor Hannahs (2004) see it this way, this can be straightforwardly analyzed as CVCVC reduplication from the stressed syllables, followed by fortification of post-consonantal consonants, followed by deletion of pre-consonantal consonants.

(39)

fá^{n}tat^{r}a	évot^{r}a
fa^{n}tat^{r}-fa^{n}tat^{r}a	evot^{r}-evot^{r}a
fa^{n}tat^{r}-**p**a^{n}tat^{r}a	———
fa^{n}ta-pa^{n}tat^{r}a	———
fa^{n}tapa^{n}tat^{r}a	evot^{r}evot^{r}a

This can be handled with the feature mechanics of the previous section that allows for one sticky-end to be positioned relative to another. In (40) the rightmost sticky-end seeks a stressed vowel, and the leftmost one will attach for segments away from it[6]. As follows from the discussion in chapter 2, the lefmost sticky end refer to the property ofbeing a consonant that follows a chain of preceding five nodes, the first of which contains F, the second of

[6]The sticky-end in (40) could be simplified with reference to syllables or feet. We will not discuss this here.

which V, the third of which C, and so on.

(40) Malagasy Attenuative (with antepunultimate stress)

$$\Big[[F] \rightarrow [V] \rightarrow [C] \rightarrow [V] \rightarrow \underline{[C]}\Big] \longrightarrow \Big[_{-} \rightarrow [*]\Big]_{F}$$

The affix in (40) accounts for the reduplication of forms with antepenultimate stress while the forms in (37) accounted for the penultimate and ultimate stress forms. Combining the two will have to wait for chapter 5.

4.7 Unpredictable Reduplicant size in Woleaian

Paster (2006, p.131-132) cites data from Woleaian taken from Kennedy (2002). In Woleaian the location of denotative marker is unpredictable: it is either reduplication of the final two syllables or gemination of the initial consonant.

(41)

feragi	'spread'	**f**feragi	'to be spread'
ŋüsü-ri	'snort it'	**ŋ**ŋüsü-ri	'to snort'
pilegü-w	'bundle it'	**p**pilegü-w	'to be bundled'
βugo-si	'tie it'	βugo-**βugo**	'to tie'
faŋoso	'current'	faŋoso-**ŋoso**	'to have a little current'
file-ti	'stir it'	file-**file**	'to stir'

Given that this is unpredictable, a solution similar to that used for Lakhota in (25) and (26) must be used. Roots can come in two forms as in (42), which the affix in (43) will reduplicate appropriately by always adding a path from segment [F] to segment [G] as in

(44).

(42) $\sqrt{feragi}$, $\sqrt{faŋoso}$

$\# \rightarrow \mathrm{f}_{F,G} \rightarrow \mathrm{e} \longrightarrow \mathrm{r} \longrightarrow \mathrm{a} \longrightarrow \mathrm{g} \longrightarrow \mathrm{i} \longrightarrow \%$

$\# \longrightarrow \mathrm{f} \longrightarrow \mathrm{a} \rightarrow \mathrm{ŋ}_{G} \rightarrow \mathrm{o} \longrightarrow \mathrm{s} \rightarrow \mathrm{o}_{F} \rightarrow \%$

(43) Woleaian denotative affix

[F] → [G]

(44) *fferagi*, *faŋoso-ŋoso*

$\# \rightarrow \overset{\curvearrowright}{\mathrm{f}}_{F,G} \rightarrow \mathrm{e} \longrightarrow \mathrm{r} \longrightarrow \mathrm{a} \longrightarrow \mathrm{g} \longrightarrow \mathrm{i} \longrightarrow \%$

$\# \longrightarrow \mathrm{f} \longrightarrow \mathrm{a} \rightarrow \mathrm{ŋ}_{G} \overset{\curvearrowleft}{\rightarrow} \mathrm{o} \longrightarrow \mathrm{s} \rightarrow \mathrm{o}_{F} \rightarrow \%$

Multiple languages similarly have reduplication of unpredictable size and in unpredictable locations. For example Rubino (2005) describes the plural formation in Pangasinan in which the size of the reduplicant in unpredictable.

	sg.	pl.	gloss
CV-	too	totóto	'man'/'people'
-CV-	amígo	amimígo	'friend(s)'
CVC-	báley	balbáley	'town(s)'
CVCV-	manok	manomanok	'chicken(s)'
Ce-	dueg	derewendg	'water buffalo(es)'

Another example is from Akuntsú. Aragon (2014) describes reduplication in this lan-

guage, which marks plurality in nouns and iterativity in verbs.

(45)

base form	pl/iterative	gloss
bawɾo	ba-bawɾo	'woodpecker'/'many poodpeckers'
ãbi	ãbi-bi	'to pull'/'to pull successively'
pi	pi-pi	'foot'/'feet'
tʃokin	tʃokin-in	'small'/'very small'
kop	kop-kop	'ripe'/'very ripe'
kapa	kapa-kapa	'to roll'/'to roll repeatedly'

We therefore have a number of examples of patterns where arbitrary information about affixes needs to be stored somewhere and I propose that if this is done with diacritics then PROP can easily account for everything. We will see more interesting examples of how this interacts with core PROP principles in future chapters.

4.8 Conclusion

I showed in this chapter that PROP and the sticky-end mechanics are capable of handling interesting cases of affixes with variable positions and reduplication with variable size. Accounting for cases in which this position or size is phonologically predictable is straightforward and simply requires to cleverly design the underlying form of the affixes. Cases that are not predictable require the root to carry some cover information that sticky-ends can utilize to attach properly. Something like this is unavoidable: the information of which forms behave in a certain way has to be somewhere, either in the underlying forms as I propose here, or elsewhere in the grammar such as listed in an vocabulary insertion rule.

The solution defended here to put things within the underlying form has several advantages. It dispenses with the complexity involved in assuming a morphological module capable storing lists of roots. It also concentrates the locus of morpheme-specific information to the underlying form.

The mechanics of affix position here does allow for some amount of phonologically con-

ditioned affix position. This might be worrisome in light of Paster (2009b), who argues against the existence of phonologically-conditioned affix position. But her argument is focused on opposing across-the-board re-orderings of the type predicted by Optimal-Theoretic constraint orders in which phonological markedness constraints ranked above morphological constraints (P≫M) drive re-orderings that resolve phonological markedness. Those would also be hard to state in PROP. Paster (2009b) however does admit variable affix position in the case of allomorphy, and in agreement with this assessment some machinery and geometry to be devised for allomorphy in chapter 5 would be needed for most cases of phonologically-conditioned affix order going beyond the complexity discussed in this section, and we will therefore come back to this topic. It is worth noting that Paster (2009b) explicitly admits one analysis using an accidentally homophonous pair of prefix and suffix to account for the case of Afar discussed above in 4.3, so perhaps, if we hope to avoid this type of redundancy, we need to admit a bit more phonologically-conditioned allomorphy than she does, albeit more restrained than predicted by P≫M OT rankings.

We will come back to these issues as we explore additional capacities that PROP allows us to handle representationally.

Chapter 5

Phonologically-Conditioned Allomorphy

Another set of phenomena that seems like it could be appropriately handled by the increased representational power of PROP is allomorphy, particularly of the suppletive kind. This chapter witll cover Phonologically-Conditioned Allomorphy (PCA) and the next one will cover Lexically-/Morphologically-conditioned Alomorphy.

The terminology of allomorphy varies by traditions and in this chapter I will use the term in a mostly descriptive sense to cover any changes between instances of a single morpheme in the line of Hockett (1954), but restricted to the type that isn't attributable to regular phonological processes. Allomorphy of the regular type that can be attributed to phonological rules will be covered in chapter 9. We will come back to terminology in 5.4 once the range of phenomena I propose to attribute to PROP is on the table.

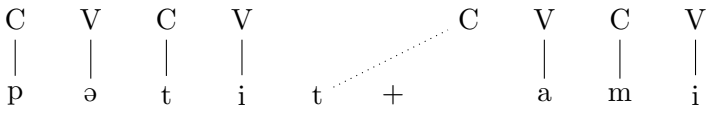
5.1 Background: representing alternatives

There is a long tradition in Phonology of analyzing patterns of allomorphy in terms of one underlying forms and some phonological processes. In a way that is the very impetus of phonological analysis notably since Jakobson (1948) and Chomsky and Halle (1968): coming up with a single underlying form per set of allomorphs and phonological rules applying to them that produce the surface variants. Phonological analysis is in a way the process of explaining morpheme alternations not in terms of morphology per se, but through a mix of clever underlying forms and regular phonological processes.

New developments in phonological representation and machinery are often accompanied by an increased capacity to encode some allomorphy in the phonology, through what I will call Single-Underlying-Form (SUF) Allomorphy. For instance autosegmental phonology has been used to analyze French liaison in terms of floating segments and pieces of a CV skeleton allowing a segment to be pronounced or not based on context. The original analysis is due

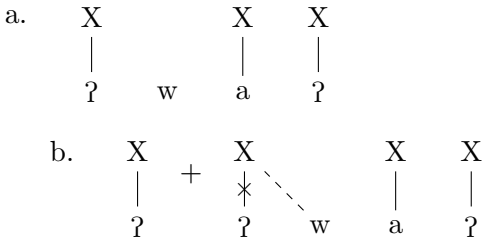
to Clements and Keyser (1983), but many variations have been offered, discussed in Tranel (1995). The following is a typical example.

(1) French Liaison



Scheer (2016) proposed that even more radical alternations could be analysed autosegmentally. He discusses the case of Caddo, in which the simple future suffix surfaces as *-ʔaʔ*, except after [ʔ] where it surfaces as *-waʔ*, without any justification in the language for a ʔ>w process. Scheer points out that the additional representational power of autosegmental phonology allows for floating segments to be put in a UR and made to surface not by rules changing a segment into another, but by simpler de-linking and re-linking processes. I.e. some apparent cases of segment-to-segment processes could actually be processes of re-linking to a floating segment that was underlyingly specified. The Caddo example could therefore be accomplished with a floating /w/ in the underlying form as in (2-a). If we then posit a rule delinking ʔ after ʔ, which is plausible as Caddo does not have geminate glottal stops at the surface, then when this suffix is concatenated with a form ending in a glottal stop as in (2-b) the glotal stop of (2-a) will delink and by autosegmental principles the timing tier autosegment will automatically relink to the available /w/, forming the form [waʔ] without any ʔ>w process in the language. i will refer to this style of analysis as Floating-Segment-Replacement.

(2) Analysis of Caddo in Scheer (2016)



This style of proposal has launched a mini-industry, largely sustained by proponents of

CVCV phonology, focused on reanalysing cases commonly analysed as involving multiple underlying forms as deriving from complex autosegmental representations (e.g. Pagliano 2003, ch.11, Barillot and Ségéral 2005, Faust 2015, Barillot et al. 2018, Faust et al. 2018). This style of analysis is entirely predicated on making full use of the representational possibilities of Autosegmental Phonology.

In parallel to this when Optimality Theory came about, its architecture, built around selecting surface forms among candidates, was very well suited to explain PCA in terms of choice among lexically-stored candidates. For instance Drachman et al. (1996) account for the allomorphy in Greek deverbal action nominals between the suffixes *-ma* and *-imo* by positing that the constraints are evaluated not against a single input, but against all combinations produced by selecting one form among a set of allomorph in a tableau like (3). This conceptualization of allomorphy is now standard in Optimality Theory, but in all its simplicity it is a radical departure from everything that came before.

(3)

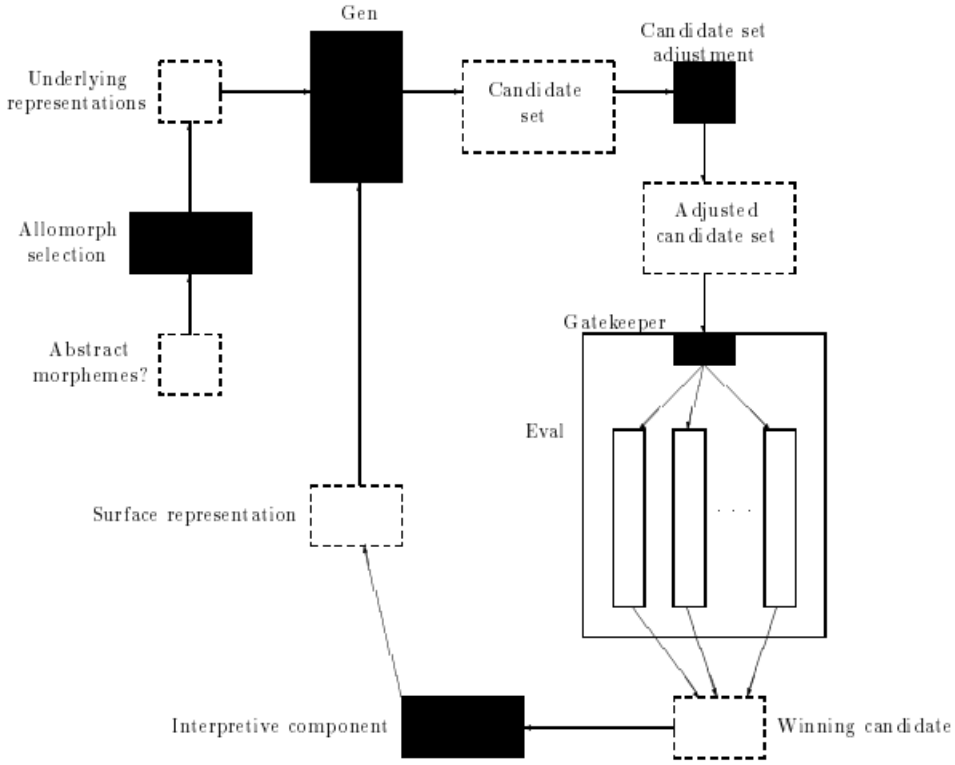
pyas-, {-ma, -imo}	FtBin	Parse2	Stem=PrWd	NonFin
a. (pyas)-(má)	∗!∗			
b. (pyás)-ma	∗!			
c. (pyás)-imo	∗!	∗		
d. (pyás-ma)			∗	∗!
e. pyas-(ímo)			∗	∗!
f. ☞ (pyás-i)mo			∗	

First it entails a very different notion of what a lexical entry is: a lexical entry is not a phonological form anymore, it is not a string of segments; it is a list of strings of segments, an object more abstract than a phonological form.

Second, like the autosegmental ideas above it places allomorph-selection in the phonol-

ogy. This stands in contrast with architectures like that posited only one year prior by Russell (1995) in which allomorph selection from abstract morphemes takes its own module.

(4) Optimality Theory Architecture from Russell (1995)



Similar SUF ideas existed even prior to Optimality Theory, such as in the work of Hudson (1974, 1975) and Hooper (1976)[1]. Hudson proposed that non-automatic phonological alternations could be represented with underlying forms containing the alternatives. For examples to account for the alternation of some Spanish verbs like *contar~cuento* Hudson uses diagrams like (5-a), which a process like (5-b) would eventually resolve[2]. In this system it is this representation of the alternatives that distinguish *contar* from non-alternating verbs like *montar~monto*, which would be have the root $/\sqrt{mont}/$, and *amueblar~amueblo*,

[1]Ultimately this type of analysis can be traced to Trubetzkoy's (1929, 2001) 'Sur la ≪Morphonologie≫', though not fully and explicitly worked out.

[2]Hudson was probably not intending for this notation to be taken literally as the underlying form, but merely to summarize lexical relationships between different lexical items to choose from, but everything in the way it interacts with phonological rules invites a literal interpretation where the bracketed form is actually inputed whole into the phonology.

which would have the root $/\sqrt{amwebl}/$.

(5)

a./k $\left\{ \begin{array}{c} \text{o} \\ \text{we} \end{array} \right\}$nt/

b. $\left\{ \begin{array}{c} \text{o} \\ \text{we} \end{array} \right\} \longrightarrow \left\{ \begin{array}{c} \text{o / [-stress]} \\ \text{we elsewhere} \end{array} \right\}$

While OT's representation required us to think of lexical storage as one degree more abstracts, storing lists of phonological representations rather than phonological representations, Hudson's diagrams suggest phonological representations themselves may be able to contain parallel segments. This is probably not what Hudson had in mind: it seems he considered the brackets to represent relationships between different lexical items within the lexicon, and not literal non-string mental objects (although I fail to see how a rule like (5) can apply to a relationship between lexical items). But we can take the notation as a serious proposal requiring us to rethink the notion of a phonological representation, allowing lexical items containing alternatives within themselves. This latter idea is more flexible than the OT solution. Unlike OT's representation of allomorphs, the alternation can be confined to only the phonemes that actually alternate. For instance in (5) the alternation is limited to the segments that actually vary: [o] vs. [we]. An OT equivalent would have to posit an input to the phonology like $\{kont, kwent\}$, and in this representation the similarity between, say, the [k] of *kont* and the [k] of *kwent* is accidental.

I will borrow some aspects of the logic of these SUF approaches to Allomorphy, particularly Hudson's representation as it can be easily implemented in PROP.

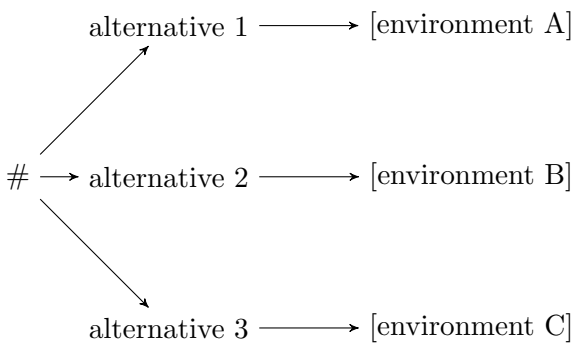
5.2 Basic geometry

Fundamentally, suppletive allomorphy is about having multiple alternative forms that cannot be accounted for by a regular phonological process. It is therefore characterizable as a problem of selection among multiple memorized alternatives based on a context.

The geometric possibility granted by PROP allows for this to happen within the phonol-

ogy with representations such as (6). In (6), an allomorphic prefix contains separate parallel paths, but in contrast to the cases of chapter 3 in which the expectations was for parallel streams to be phonetically compatible and all attach, allomorphy results from the scenarios in which (in the simple case) only one of the alternatives successfully attaches to a stem, in which case only one of the alternatives is part of a complete path from # to %. There is no expectation that the streams be compatible, since they never actually end up truly in parallel in any finished graph, as (again, in the simple case) only one of them is actually attached at both ends.

(6)



5.3 Examples

5.3.1 Consonant/Vowel Sensitivity in Korean

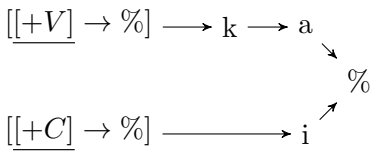
First consider cases of phonologically conditioned allomorphy as in (7). In Korean the nominative suffix is [i] after a consonant and [ka] after a vowel. This can all be handled with technology we already have as in (8). The top sticky-end seeks a final consonant and the bottom one seeks a final vowel. Assuming it only finds one of those at a time, the form will contain only one path from # to %. The graphs of *mom-i* and k^h*o-ka* will look like (9)

and (10) respectively.

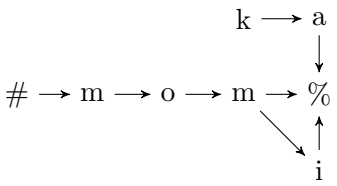
(7) Korean nominative allomorphy (Nevins, 2011, p.7)

mom	-i	'body'
$k^h o$	-ka	'nose'

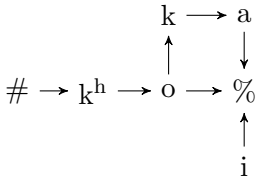
(8) Korean nominative morpheme



(9)



(10)

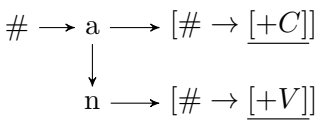


5.3.2 Partial suppletion in English *a/an*

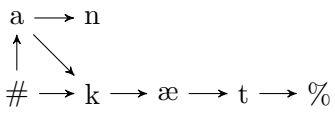
Additionally, just in like Hudson's diagrams, PROP allows allomorphs to share segments they have in common. For example the English *a/an* allomorphy can be handled with the

same machinery as the Korean case, except only one [a] is needed[3].

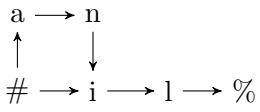
(11) a/an



(12) *a cat*



(13) *an eel*



5.3.3 ± Approximant sensitivity in Swedish

Phonologically-conditioned allomorphy targeting specific features can also be defined in this way. Consider the Swedish en/n allomorphy. Leaving aside some exceptions with [l] (see Löfstedt 2010), the form -*n* is used for vowels and liquids, whereas -*en* is used for nasals, fricatives, and stops. This can be described as sensitivity to ± Approximant. We can therefore account for this behavior with sticky-ends sensitive to ± Approximant as in (15),

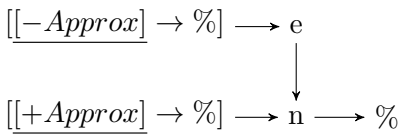
[3]I am assuming here that *a* and *an* do in fact have a vowel in common, which is probably not true in varieties of English where /e/ and /ʌn/ may be more accurate. The example is mostly illustrative.

which will attach to the roots *by:* and *gru:p* as in (16) and (17), respectively.

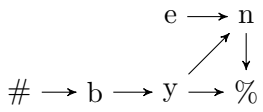
(14) Swedish definite suffix allomorphy, data from Nevins (2011) and Löfstedt (2010)

	indef.	def.	gloss
a.	by:	by:n	'village'
b.	syk:el	syk:eln	'bycicle'
c.	pilgrim	pilgrimen	'pilgrim'
d.	i:s	i:sen	'ice'
e.	gru:p	gru:pen	'hole'

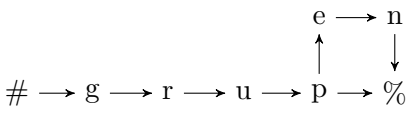
(15) graph of *en/n*.



(16) *by:n*



(17) *gru:p*



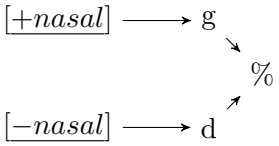
5.3.4 ±Nasal sensitivity in Nishnaabemwin

A similar pattern of harmony showing sensitivity to a specific feature is found in Nishnaabemwin. Valentine (2001, p.221-223,227), Paster (2006, p.93) and Scheer (2016, p.353) discuss the allomorphy in the 3rd person suffix in the VAI conjunct. This third person suffix has

the form -*g* following a nasal and -*d* elsewhere. This alternation does not appear to have any phonological reason since sequences of [nd] are found elsewhere in the language.[4]

This pattern is readily accounted for as sensitivity to the feature ±nasal with a suffix like the following:

(18)



5.3.5 Feature-level suppletion in Bari

Allomorphy in PROP can be stated at the level of alternating individual features rather than entire segments. Paster (2006) discusses the Bari causative/reciprocative prefix. The vowel of the prefix undergoes ATR harmony with the root, and is otherwise +high before a root with a +low vowel and -high before a root with a -low vowel. Following Paster's notation in the following examples <ə> is a low +ATR vowel and <a> is a low -ATR vowel.

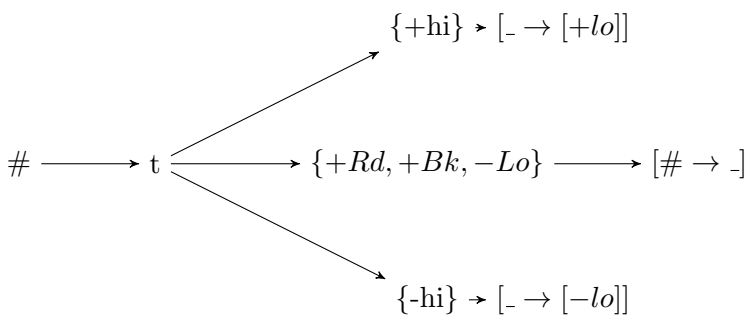
[4]It is worth mentioning the phonetic outcome of this /-g/ which is never clearly summarized in one place in any of the works cited above: all the /N+g%/ sequences formed by this allomorph apparently surface as [ŋ]. Valentine does mention a phonological process of assimilation followed by deletion (p.74) that causes /n+g%/ sequences to surface as [ŋ], but there is also scattered evidence that /m+g%/ also surface as [ŋ] as Valentine gives multiple examples of /m/ assimilating in place to following consonants, e.g. the suffix /-m/ indexing an unspecified actor assimilating to the third person marker (p.222), the theme suffix /-am/ assimilating to /s/ and /k/ (p.308), and the root $\sqrt{waabam}$, "see" to the VTI third person suffix /-d/ as *waaban-d-am* (p.305).

(19) Bari causative/reciprocative

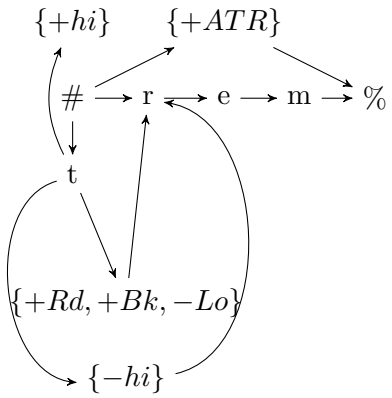
nək	'to suck'	tu-nək	'to give suck'
ŋa	'to open'	tʊ-ŋa	'to open with force'
rik	'to drive away'	to-rik	'to pursue'
gwut	'to beat'	to-gwut	'to beat each other'
rem	'to stab'	to-rem	'to cause to stab; to stab each other'
mor	'to insult'	to-mor	'to abuse violently; to insult each other'
mɛt	'to see'	tɔ-mɛt	'to look at each other; to cause to see'
kɔr	'to divide'	tɔ-kɔr	'to settle a dispute'
yɪŋ	'to hear'	tɔ-yɪŋ	'to listen attentively; to attract attention'
kʊr	'to till'	tɔ-kʊr	'to help each other with the tilling'

This can be handled with an affix like (20). The part of the prefix common to both allomorphs, /t{+*back*, −*low*, +*round*}/, will invariably attach as a normal prefix, whereas the choice between +high and -high will depend on the quality of the vowel. When this attaches as in (21) the harmonic ±ATR value will come from the root in the way defined in chapter 3 with a parallel path that prefixes are put in parallel to, and the height of the vowel will depend from whether the +Low or the -Low sticky-end has successfully attached (as the other is not part of a path from # to %.

(20) Bari causative/reciprocative prefix



(21) *tɔ-kʊr*



5.3.6 Default allomorphs

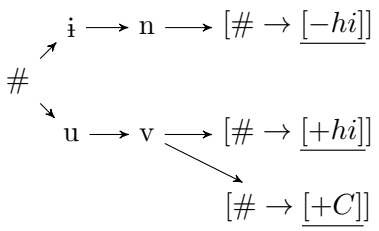
Not all cases of phonologically-conditioned allomorphy involve complementary distributions both sides of which are natural classes. For instance consider the distribution of the perfective in Kwamera, which Lindstrom and Lynch (1994) report as being *i̵n-* before [-hi] vowels and *uv-* before [+hi] vowels and consonants, e.g. *r-uv-regi*, 3sg.perf.hear, vs. *r-i̵n-atu*, 3rd.perf.see[5]. Since high vowels and consonants are not a natural class, there is no single sticky-end that can accommodate this pattern of allomorphy.

There are at least two ways to handle such cases. The way that does not require any new machinery would be to give one allomorph a set of sticky-ends covering the relevant natural classes as in (22). This would adequately account for all the data in a sort of 'brute force' way, with at least one path from the prefix to the root whether that prefix starts with a high vowel or a consonant. Although descriptively sufficient here, this option would prove unable to handle productive affixes in the case of Morphologically Conditioned Allomorphy

[5]As observed already by Paster (2006, p.32), Linstrom & Lynch do not give any example of *uv* used before a high vowel. More worryingly they also offer examples of *i̵n-* before /u/ and of *uv-* before /a/. On close analysis of the paper it seems that the latter are the result of mistaken glosses confusing the exponent *uv-* of the perfective with the verb *uv* elsewhere glossed as 'move' or 'proceed', but I have no explanation for the former. Like Paster (2006), Boutin (2009), and Scheer (2016) I will assume that the claim is correct here because this example is eminently simple and useful for the expository claim at hand and I find it implausible that Lindstrom & Lynch would have made such an error.

in the next chapter where there is no set of phonological features to brute force upon.

(22) Brute force version with multiple sticky ends.



An alternative would be to design a mechanism that can accomplish the equivalent of selecting 'defaults', so that one sticky-end can be specified for its environment and another represented as default to form a path only if the other sticky ends have not successfully attached. One sticky-end needs to be defined for a specific environment and the other for a more general one. The issue that immediately arises though is that in the case of the more specific environment we predict both allomorphs attaching without an obvious way to decide which path to follow. In fact if anything given the discussion in chapter 3 we would predict both paths to be followed in parallel, contrary to fact.

There are a number of ways we could try to accomplish defaults with pure PROP machinery by taking advanatage of sticky-ends or parallel structures. Here are a number of sensible proposals:

One option would be to make it about sticky-ends and the segment they attach to, e.g. forcing the de-linking of the default form in case the segment it attaches to is also attached to the non-default sticky-end, namely making the sticky-ends mutually exclusive. This would amount to making the Kwamera perfective's [# → [−*hi*]] and [# → [+*C*]] incompatible. A version of this would be to posit an Elsewhere Condition on attaching multiple sticky-ends to the same segment that always favors the most specific one and blocks the others.

Another logical option would be to attribute the default behavior to the phonetic incompatibility between [ɨn] and [uv], forcing the articulators to choose one of the two. This would amount to letting both versions of the prefix attach and let the choice be made later.

The argument against the generalizability of these two options is that not all allomorphs 'compete' for attachment to the same location in positions that make them parallel to each

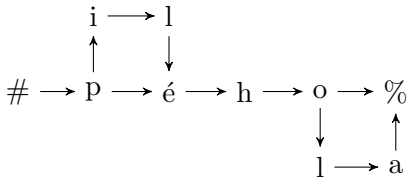
other. For instance consider the Nakanai nominalizing affix as described by Paster (2006): the form -*il*- is used before a stressed first vowel of the word which, given the regular penultimate stress pattern of the language, means words of one or two syllables. In any case where the stressed vowel is not the first vowel a suffix -*al* is used instead.

(23) Nakanai nominalizing affix

pého	'die'
p-**il**-ého	'death'
vi-kúe	'fight(v.)'
vikúe-**la**	'fight(n.)'

This is a case of PCA with a default, but crucially the infix -*il*- and the suffix -*la* are not competing for attachment to the same location, nor are they being attached in parallel as we can see in (24). There is no way to attribute this to a local effect of the sticky-ends or to phonetic incompatibility. Whatever regulates de-linking or non-attachment must be non-local.

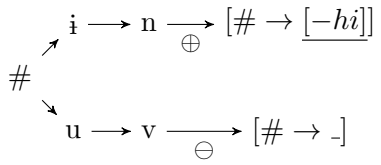
(24) **p-il-eho-la*



Of course any encoding of defaults will make the theory more complex, but with the goal of being able to discuss more patterns of allomorphy I will here describe and use an implementation with non-local dependencies between precedence links themselves. I have strong hopes that this idea can eventually be superseded.

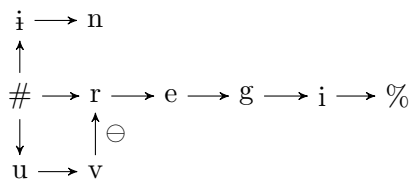
This dependency is such that after attachment, precedence links marked with $\ominus$ delink if the ones from the same affix marked with $\oplus$ have been successfully created. The Kwamera perfective could be formulated as in (25), with a specific sticky-end seeking initial [-high] segments whose precedence link is marked $\oplus$ and a more general sticky-end seeking any initial segment whose link is marked $\ominus$.

(25) Version with a $\oplus/\ominus$ default

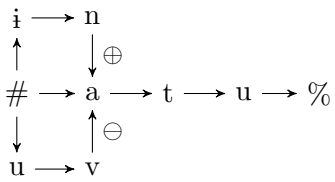


In the case of a consonant- or high-vowel-initial root the graph will be as (26) with an unambiguous path through *uv*. However in the case of a non-high vowel both sticky ends will attach and then the $\ominus$ path will delink as in (27), creating a single unambiguous path through *ɨn*.

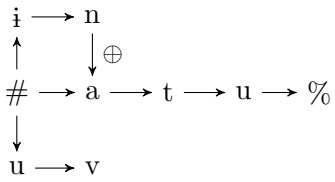
(26) *uv-regi*



(27) *ɨn-atu*

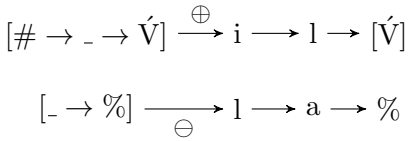


⊖ delinking

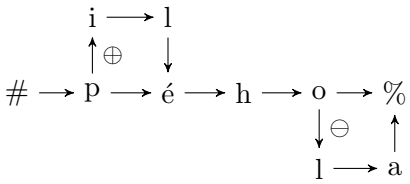


Similarly, the Nakanai nominative will look as in (28) (a single disconnected graph), and will attach to a stress-initial form as in (29). ⊕/⊖ allomorphy lets us express this in PROP as the attachment of *-al* being dependent on the non-attachment of *-il-*. I currently see no other way to describe this pattern.

(28) Nakanai nominative



(29) *p-il-eho*



There are three reasons why I would rather talk of de-linking some precedence links rather than about blocking them from linking in the first place. First, the latter option would involve forcing an order of attachment over the sticky-ends which would be more complicated. Second, some analyses below will require $\ominus$ on precedence links that are not directly added by a sticky-end, hence preventing linking would not be enough.

And the third reason is that with this linking and de-linking there is a stage in the derivation where there was indeed a link from the default to the root, and hence a path through the graph going through the default affix. This could play a processing role in explaining why the use of an ungrammatical default affix on an inappropriate root, e.g. *oxes* for *oxen*, or *catched* for *catch*, remains parsable by a native speaker. In the current proposal, there is a stage in the derivation of a non-default affix in which one path through the graph does cross the default affix. Assuming that lexical parsing involves some amount of identifying paths through graphs, it allows for these ungrammatical forms to be retrievable by a native speaker even though they would never utter them.

There are also analyses that suggest that other operations may happen during this intermediate stage in the derivation between linking and de-linking, perhaps even to the point of bleeding the $\ominus$-delinking rule. We will see such an example in Catalan in 6.1.4.

Although we have now been forced to posit a new piece of machinery taking us further from the PROP ideal, this Nakanai example illustrates a way in which the PROP analysis is superior to other phonology-internal attempts at SUF allomorphy, discussed in 5.1. The Hudson-Hooper model with brackets cannot handle alternatives that are not competing for the same string location, and the classical OT analysis requires selecting an underlying order between morphemes that makes it hard to even define allomorphs competing for different locations[6]. The representational power of PROP that allows representations like (28) in which both linear order and allomorph-choice to remain undetermined until after spell-out, is uniquely well suited for this situation.

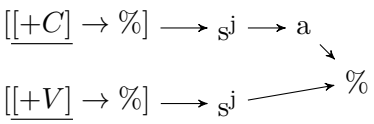
5.3.7 Non-sticky-end default in Russian and Tahitian

The use of $\oplus$ and $\ominus$ does not have to be restricted to precedence links added via a sticky-end. This is useful in cases of allomorphy relating to changes other than at the point of contact between an affix and a root. Consider the Russian reflexive discussed in Paster (2006, p.54), which is -s^j after a vowel and -$s^j a$ after a consonant. This could be done as in (31) without the use of $\oplus$ or $\ominus$.

(30) Russian reflexive

a kupaju-**s$^{\mathbf{j}}$**	'I bathe myself'
on kupajet-**s$^{\mathbf{j}}$a**	'he bathes himself'

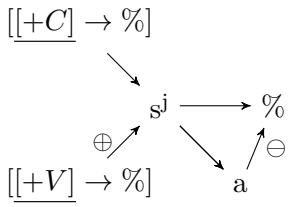
(31) Russian reflexive suffix (two /s$^{\mathrm{j}}$/ version)



[6]Versions of OT attributing the location of infixes to the representation, e.g. Svenonius and Bye's 2011 mechanics of antitropism, would fare better. This, in my opinion, comes from the insight of attributing affixation location to the representation, just like PROP does with sticky-ends. But even these require an underlying concatenative order, which makes it a challenge to analyse the Bari affix which aligns leftward in one case and rightward in the other.

However (31) is unsatisfying in at least one respect: it implies that the the /sʲ/ of -*sʲa* is not the same as the /sʲ/ of -*sʲ*. This is definitely at least counter-intuitive, even though it would result in a correct output. But the use of ⊕ and ⊖ allows us to have a single /sʲ/ across both forms as in (32). The link from /a/ to % is not connected to any sticky-end, but it will de-link if the sticky-end marked with a ⊕ does connect, i.e. in vowel-final forms, leaving no path through /a/.

(32) Russian reflexive suffix (one /sʲ/ version)



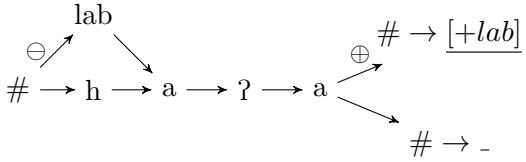
Again this same strategy can be applied to individual features. The Tahitian causative/factitive, described in Paster (2006, p.39-40) has the form *ha'a* before labials and *fa'a* elsewhere. Assuming that [h] is a segment underspecified for place and therefore the only difference between [h] and [f] is absence vs. presence of a labial feature, the prefix can be formulated as in (34). In this prefix, the precedence link leading to the labial feature will de-link if the sticky-end finds an initial labial, making the fricative an [h].

(33) Tahitian causative/factitive

ha'a-veve 'appauvrir'

fa'a-tai'o 'faire lire'

(34) Tahitian causative/factitive prefix



5.3.8 Opaque Allomorphy in Japanese

Japanese has a pattern of PCA that interacts with a phonological rule discussed in Nevins (2011, p.18), Kubozono (2015, p.367-368, 373), and Hall et al. (2018). A number of Japanese suffixes are phonologically conditioned by whether they follow a vowel or a consonant. For example /(r)u/, sometimes glossed as non-past (Nevins, 2011), present (Kubozono, 2015), or infinitive (Hall et al., 2018), appears as [-ru] after a vowel and [-u] after a consonant, and the negative /(a)nai/ appears as [-nai] after a vowel and [-anai] after a consonant, as one can see in the contrast between these affixes on roots /yom/ 'read' and /ne/ 'sleep'.

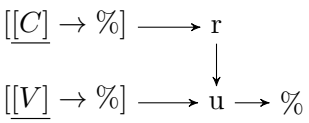
(35)

	/yom/ 'read'	/ne/ 'sleep'	/iw/ 'say'
NON-PAST	yom-u	ne-ru	i-u
NEGATIVE	yom-anai	ne-nai	iw-anai

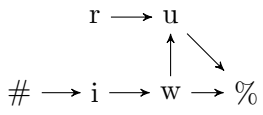
However this pattern of PCA interacts with a phonological process: /w/ deletes before all non-low vowels, and yet the suffixes surface in their pre-consonantal forms despite ending up in pre-vocalic position, as one can see for the non-past form of /iw/ in (35), which surfaces as [i-u] and not *[i-ru].

The allomorphy itself is easy to handle in PROP with an affix like (36) attaching as in (37).

(36)

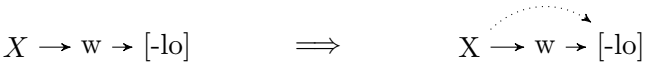


(37) /iw + (r)u/

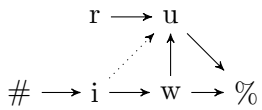


Then if the phonological deletion is handled as in (38) through adding a path, this will convert the graph in (37) into (39), which is what we want.

(38) *w*-deletion



(39) *i-u*



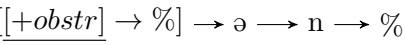
The possibility of opaque allomorphy easily follows from PROP assumptions, as the attachment of allomorphs deciding paths happen prior to phonological rules.

5.3.9 Non-Attaching Allomorphs

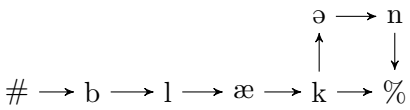
A final geometric possibly to discuss is the situation in which some allomorphs are phonologically-conditioned and the default is phonologically null. Consider the English verbalizer *-en*, which attaches only to adjectives ending in obstruents: *to redd-en*, *to moist-en*, *to thicken-en*, vs. *to green*, *to dry* , *to thin* (cf. **to green-en*, **to dry-en* , **to thin-en*).

This can be handled with a suffix like (40). In the case of a word ending in an obstruent this will attach without issue and form the structure of a simple suffix.

(40) *English verbalizer -en*

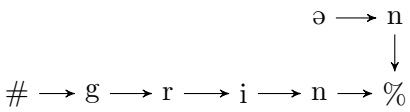


(41) *black-en*



However in the case of a root ending in a sonorant the sticky-end will not find anything to attach to and will therefore not be part of any path from # to % as in (42).

(42) *green (v.)*



This analysis somewhat captures the spirit of Zwicky (1985) who proposed that situations like this did not need to be analyzed as contextual zero-allomorphs, but could simply be analyzed as a lack of any allomorph meeting the structural description. This is similar in that I do not posit any part of the morpheme in (40) to seek out the default case as zero, it is a lack of attachment that causes the zero realization. However the analysis here contrast with Zwicky's in that where he posits a lack of morpheme, I posit that the verbalizer is in fact there, except without any part of it that is traversable, and hence without a part that will end up pronounced.

There are some complications to the generalization above. For instance there needs to be exactly one final obstruent, and final /t/ doesn't count as it deletes, e.g. *soft-en* [sɔfən] (leading Booij (2012) to refer to this as a surface constraint, and thus evaluated after *t*-deletion. This pattern may be better analyzed as (43).

(43)

$$[[-obstr] \rightarrow \underline{[+obstr]}]_{\text{ə}} \longrightarrow \text{n} \longrightarrow \%$$

But even this generalization has problems, e.g. *to crisp-en* and *to wast-en* are sometimes attested.

Either way the logic of the discussion below is valid regardless of the details of the generalization, as long as there is a set of environment taking *-en* and a set of environment surfacing without an overt ending (which may not be the case).

5.3.9.1 Summary of PCA

The approach to allomorphy presented so far in this chapter is roughly a 'selection' model in the sense of Bye (2007) and Paster (2006) in that it relies on allomorphs being specified for their environment rather than on any optimization effects. However this is accomplished without without the architectural implication that a morphological module in charge of allomorph section has to precede the phonological module. 'Selection' here is performed internally to the phonology, selection arising as a side effect of sticky-ends, not through optimization. We will come back to this discussion at the end of this chapter.

5.4 Further Issues

With the range of allomorphy phenomena I suggest to analyse using SUF allomorphy in PROP made explicit, I will address what the approach outlined here has to say with regard to a number of theoretical issues.

5.4.1 Terminology: 'Allomorphy', 'Suppletion', 'Irregularity'

I have used 'allomorphy' in a vague descriptive sense here because most of the typical uses of allomorphy-related terminology is founded on assumptions that poorly apply to the SUF approach of this chapter.

For instance a mainstream use of the term 'allomorphy' defines it as cases in which alternations in surface forms require multiple URs, in contrast to alternations that can be attributed to a single UR and regular phonological processes applying to it (e.g. explicitly in Matthews 1974, Lieber 1982, Zwicky 1985, Kiparsky 1996, Bonet and Harbour 2012, Faust and Lampitelli 2016, and implicitly in many others) By this usage, the claim of this chapter is that there is no such thing as allomorphy, a confusing claim in my opinion. But indeed the goal of this chapter is to account for all allomorphy-in-the-wider-sense with a single UR and phonology-internal processes applying to it, sometimes in the form of phonological rules and sometimes with sticky-ends selecting among alternative. If allomorphy is having multiple URs, the claim of this chapter is that there is no such thing as allomorphy as all suppletion comes from SUFs.

This usage stands in stark contrast with the complete opposite usage of 'allomorphy' to refer only to the result of phonological rules to the exclusion of any suppletive or conditioned forms, as in the *Language Files* textbook (Dawson and Phelan, 2016), in which allomorphy is illustrated with the example of the [m]~[n]~[ŋ]~[ɹ]~[l] negation prefix, and the [s]~[z]~[əz] plural (p.181) and defined as 'a set of non-distinctive realizations of a particular morpheme that have the same function and are phonetically similar' (p.690). Another example is Fábregas and Scalise (2012) in which they claim that 'allomorphy in its traditional sense requires the two forms to be derivable from the same phonological representation' (p.82). Proponents of the allomophy=regular-phonology version tend to think of suppletion as a word-formation *process*, whereas proponents of the allomorphy=different-URs use 'suppletion' as a more descriptive term for alternations that require memorizing more things. By this usage that opposes allomorphy to suppletion, the claim of this chapter is arguably that there is only allomorphy and suppletion does not exist.

These two uses, however contradictory, are predicated on the same premise, namely the existence of a deep architectural split between the mechanism that yields common alternations describable over phonemes alone, and the ones that yield idiosyncratic and sometimes major alternations in forms that require reference to specific morphemes. In the SUF PROP model presented so far this split does not exist. All lexical items arrive in the phonology and it is there that the phonological material attaches and undergoes phonological processes, leaving some surface form to be pronounced. There is no deep architectural divide, and the differences emerge from the interaction of the different items that can be sent to the phonology and the rules that can happen to them while there.

A new terminology was recently suggested by Haspelmath (2019), who discusses how the term 'morpheme' itself is subject to a similar ambiguity to 'allomorph', with different theories refering e.g. to the two forms of the plurals *book-s* and *ox-en* either as two homosemous morphemes expressing plural meaning, or as 'members' of the same morpheme [Plural]. Haspelmath proposes to call alternants like *-s* and *-en* different *morphs* part of the same *morph set*, whereas [z], [s], and [əz] are the same morph. But even in these new terms intended to be neutral it is unclear how to phrase the claim of this chapter: we could adopt the terminology as a surface description and frame this chapter as claiming that morph sets are stored in a single UR. Or we could adopt the terminology as a theoretical claim and frame it as claiming that all morph sets are singletons and all surface variants derive from a single morph, including *-en* and *-z*.

Yet another definition is found in Tranel (1992): he defines suppletion as 'the lexical listing of more than one allomorph for a given morpheme'. But we are faced with the same problem: is a complex underlying form containing both *-en* and *-z* a listing of multiple allomorphs? There is in fact only one vocabulary item, but in another sense there is a listing of multiple allomorphs, namely within that vocabulary item.

5.4.2 PROP vs. Hudson & Hooper

As mentioned at the beginning of this chapter, the intellectual predecessors of the ideas presented here include the ideas of Hudson (1974, 1975), and Hooper (1976), as the PROP analysis of allomorphy involves packing the variants of a form within a single UR. I therefore must address some of the criticisms that have been levied against those ideas.

Though they do not explicitly cite Hudson or Hooper, Kenstowicz and Kisseberth (1979, p.180-204) offer an extensive critique of ideas that are very recognizably theirs. We will see that the critique is irrelevant to the proposal of this chapter. They largely attack the use of alternants in the UR to handle what regular phonological rules handle in Generative Phonology. E.g. they are attacking a theory of the English plural as in (44) supplemented with statements such as "chose [s] after a voiceless non-sibilant". I.e. they are objecting to the use of alternants to account for regular predictable alternations. They object that these statements end up recapitulating the phonological and phonotactic generalizations of the language. They also object that this approach fails to explain the existence of completely general alternations affecting all instances of a certain segment in the same contexts.

(44)

$$\text{kæt} + \left\{ \begin{array}{c} \text{s} \\ \text{z} \\ \text{ɨz} \end{array} \right\}$$

These objections do not really affect the ideas presented here, as I am only concerned with the unpredictable alternations, the case where regular phonology is not enough. I agree with Kenstowicz and Kisseberth that abstraction in representation is required by the

data.

Plus, although superficially similar when looking at the representation of alternation as in (5) and (44), there is really little else in common between the theory of Hudson (1974, 1975), Hooper (1976) and the ideas of this chapter. Hudson and Hooper were motivated by a desire for 'concreteness' in representation and were essentially opposed to levels of representation that are not pronounceable due to abstract archiphonemes or due to violations of the languages phonotactics prior to repair.

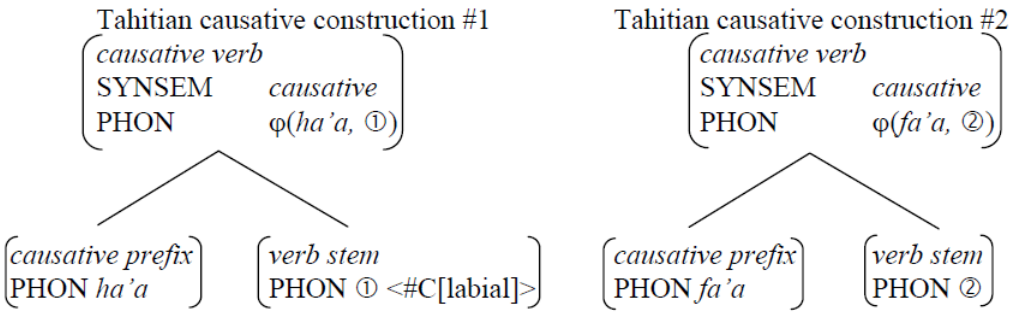
So while PROP allomorphy can be said to be similar to the ideas of Hudson and Hooper, it does not share the same problems.

5.4.3 PROP vs. Subcategorization

Paster (2006) argues in favor of a subcategorization model for Phonologically-Conditioned Suppletive Allomorphy (PSCA). She proposes that affixes come with subcategorizational requirements, specifications of what the affix needs in order to surface. PSCA results from the cases where different affixes with the same meaning have different subcategorizations. This therefore embeds PSCA in a general theory of bound morphology and unifies it with syntactic c-selection in a constructional framework.

Recall the Tahitian Causative in 5.3.7, which is *ha?a* before a labial and *fa?a* elsewhere. Paster proposes that Tahitian has the following two constructions:

(45) Paster's 2006 constructional subcategorization analysis of Tahitian (p.12)



This approach unifies all PSCA, including the optimizing type and the non-optimizing type, in contrast to varieties of OT that handle the two differently.

I will not discuss Paster's analysis, which is so radically different from anything discussed

here that there is little communication to establish, however Paster derives the following four predictions from her model:

(46) Predictions of Paster's subcategorical model for PCSA (p.257)

1. PSCA is not always phonologically optimizing
2. PSCA is sensitive to phonological elements in underlying/input forms, not surface forms
3. Phonological conditions on PCSA can come only from the 'inside'
4. Affix allomorphs occur adjacent to the phonological elements of stems that condition their distribution

She substantiates these predictions with an extensive typological survey of PSCA, so it would be useful to see whether PROP SUF allomorphy derives them too.

The first point is definitely predicted here. Allomorphy is performed by affixes that seek phonological features with sticky-ends and there is nothing in the system constraining these, so allomorphy is arbitrary and free to be non-optimizing.

The second prediction follows since phonological rules cannot happen in PROP between a stem and an affix prior to attachment, and therefore the attachment responsible for allomorphy cannot be sensitive to any phonological rule affecting the stem triggered by the root. We have already discussed a case of opaque PCA above in 5.3.8. Wolf (2008, ch.3) .

The third prediction only partially follows from PROP, and that's a good thing. Given that attachment of an alternative or another is the determinant of allomorphy in PROP, it follows that the main way for allomorphy to be realized is 'inner' lexical items conditioning 'outer' ones. However there are limited ways in which outer material can phonologically condition the allomorphy of inner lexical items and those are possible in PROP. We will discuss this in the next subsection.

And finally the linear-adjacency condition follows too since allomorphy in PROP is decided upon attachment. In PROP the same mechanics that determines the attachment point of an affix also determine its allomorphy. This non-stipulatively derives the prediction.

This is an important one because a linear adjacency condition on allomorphy has been noted by others, notably in Embick's 2010 C_1-LIN Theory which posits both a syntactic cyclic condition on allomorphy and a linear adjacency condition. PROP has nothing to say about the former, which may properly belong to syntax and the hypothesis of cyclic spell-out, but the latter condition follows from PROP and much more satisfactorily so. Embick has to resort to a stipulation of the linear adjacency fact which he has to state on an ordered tree since he posits allomorphy to be decided prior to insertion. PROP on the other hand is compatible with a non-linearized tree structure in syntax.

5.4.4 Outward-sensitive allomorphy, and root allomorphy

We saw in the last section that doing PCA with sticky-ends derives the prediction that phonological conditioning can only come from the inside, based on the fact that it is usually determined by sticky-ends attaching to a stem. But there is one family of exception to this generalization and PROP also derives it.

I am referring to cases such as the Spanish *kont kwent* mentioned at the beginning of the chapter. The form is sensitive to stress, taking the form with [we] when stressed forms and the form with [o] when unstressed. Because Spanish stress is computed from the end of the word, whether the root vowel is stressed or not is not known to the phonology by the point in the derivation in which the root is spelled out. Bermúdez-Otero (2013) gives the paradigm in (47). Because the choice of allomorph in *contador* must be delayed until the stress is assigned to the suffix *-dor*, it cannot be determined at vocabulary-intertion.

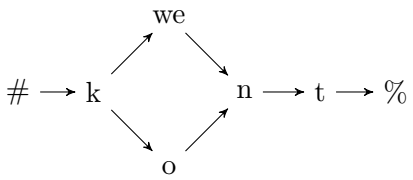
(47)

kont-á-ɾ	'count.INF'
kwént-a	'count.3SG'
kont-a-ðóɾ	'counter'

In PROP this is relatively easy to account for. The root $\sqrt{cont}$ has the form in (48),

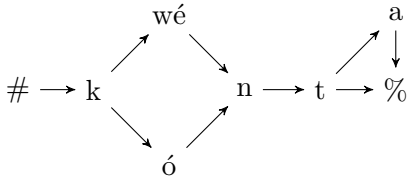
inspired by the analysis of Hudson (1974, 1975).

(48) $\sqrt{cont}$



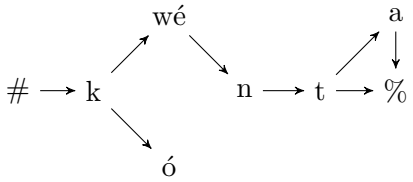
Without going into the details of stress assignment in PROP (we will briefly come back to stress in ch. 9) it suffices that the mechanism that assigns stress to the penultimate vowel in forms with -[a] and to the final vowel in forms in -[aɾ], assigns the stress to *both* alternants of the root $\sqrt{cont}$ as they are both in penultimate position.

(49) *cuent-a*



Given a rule de-linking ó→ X if this X follows another stressed vowel, we can obtain the graph in (50) with an unambiguous path through [wé]. An opposite rule de-linking unstressed we→ X if this X follows another vowel will account for the cases with [o][7].

(50) *cuent-a*



The advantage of PROP is again that we can only account for this pattern because the choice between [kwent] and [kont] is not decided right away, but is delayed until later. This type of allomorphy is not possible in a system where allomorphs must be decided at

[7]We will see a perhaps more elegant analysis of this allomorphy dispensing with de-linking in 9.3.4

insertion.

This type of phenomenon is the reason all models positing immediate resolution of allomorphy had to come up with ancillary assumptions to handle such cases of "late allomorphy". This is why the traditional Generative account is a phonological solution in the form of an archiphoneme like /O/, whose resolution is phonology-internal. And in Distributed morphology the above would likely be handled with a re-adjustment rule, a separate mechanism to introduce variants of a morpheme within the phonology. Both of those solutions are attempts at getting around the fact that some cases of PCA are delayed until after insertion. PROP on the other hand does not need any extra mechanism to do that, as both variants are allowed to cohabit in the form for the entire derivation.

Although plausible for the *kwent~kont* case in Spanish, the phonological solution is unlikely to generalize well to all similar cases. Italian has a rich set of such prosodically-determined allomorphs as described in Wolf (2008, p.194): e.g. the root of the italian verb *rompere*, 'to break', surfaces as *rúpp-* when stressed and *romp-* when unstressed. Multiple roots are in the same boat including those of *muovere* 'to move' (*móss-* vs. *m(u)ov-*), *prendere* 'to take' (*prés-* vs. *prend-*), and *andare* (*vá-* vs. *and-*). No single archiphoneme seems capable of deriving all of these changes.

This last example of *andare* makes the readjustment solution very unappealing too. An alternation like [and]~[vá] is not the type of 'small' change that readjustment rules have usually been posited for, but a complete suppletion. If readjustment can convert [va] and [and] into each other then it simply recapitulates all the power of allomorphy that DM attributes to contextual insertion. Readjustment in DM has already been extensively criticized from a DM-internal perspective for being uneconomical, redundant, and/or unconstrainedly defined (Siddiqi 2006, 2009; Bermúdez-Otero 2012, 2013; Haugen and Siddiqi 2013; Merchant 2015; Haugen 2016), so I will not belabor the point here.

But also importantly for PROP, cases of outward-sensitive PCA are very limited. Unlike allomorphy caused by sticky-ends, which can target any phonological properties of what they attach to, allomorphy of the *kwent~kont* type is limited to what can be formulated as a regular rule manipulating the graph, and can only be sensitive to the outcome of regular processes; it cannot retro-actively force the attachment of allomorphs that failedto attach.

All the cases of outward-sensitive allomorphy I am aware of involve sensitivity to stress and can be done in PROP in the manner described above for Spanish.

This analysis in terms of root allomorphy that is resolved late offers an answer to the problem that forms the starting point of Bermúdez-Otero (2013). Bermúdez-Otero is concerned with the problem of forms like **cuentadór*, in which the stress pattern can only be determined after the insertion of the suffix *-dor*, which, assuming as DM does that category-defining heads create a cycle, is in a separate cycle from the root. In DM since allomorphy happens at insertion, it would have to be fully decided by the end of a cycle. However in PROP there is no reason for such an order: insertion of both variants happens, and the ultimate choice can be delayed. Contra Bermúdez-Otero (2013, p.58), we have a root-driven theory of morphology in which allomorphy is not answered 'in the first cycle'.

5.4.5 The gradability of suppletion

Mel'čuk (1994) discussed what he termed the 'gradable' character of suppletion by observing that many cases of suppletion seem partial. He points out the example of French *pø* vs. *puv-* 'can, be able to'. There is an intuition that the [p] of both allomorphs are 'the same [p]' in a sense, and we may seek to capture that in the theory. In a theory of suppletion with multiple URs this would not be possible: the grammar would have a lexical item /pø/ and a lexical item /puv/ and the similarity between the first segment of each would be (synchronically) a coincidence.

Mel'čuk offers the possibility that this may be derived by a restricted rule ø>uv. Nowadays this possibility would be phrased as readjustment, which we discussed in the previous section. Again, an advantage of PROP is that it can derive this pattern without resorting to such machinery as lexically-specific rules that are often very powerful.

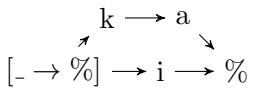
In PROP the gradability of suppletion follows directly from what suppletion is in the theory: multiple alternatives within a phonological represntation. Since these alternatives are stated within one lexical they can be stated at any level of precision the language demands.

5.4.6 PROP and surface optimization

One logical possibility that will inevitably cross the mind of many readers would be to incorporate surface optimization into this PROP account of allomorphy. E.g. one may be tempted to dispense with overly specific sticky-ends and with ⊕/⊖-defaults and let the final path through the graph be resolved not by fiat, but by selection of a phonetically optimal path.

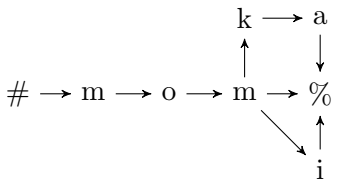
For instance recall the korean PCA in 5.3.1, in which the nominative *-ka* is chosen after vowels and *-i* after consonants. This could plausibly be reanalyzed with an affix like the following, which contrasts with (8) in lacking sticky-ends seeking vowels or consonants.

(51) Korean nominative suffix without selection via sticky-ends



Seeking only a final segment, both alternatives will therefore attach to a root, as in (52), which contrasts with (9) in having a path from the [m] of the root to the [k] of the suffix.

(52)



The final step would be to posit that it is the graph in (52) that is passed onward, and that it is a phonetic principle, e.g. a preference for C→V over C→C, that forces the surface pronunciation to be *mom-i* and not **mom-ka*. One could even expand to embedding PROP into an OT grammar with constraints over paths or the like. This is indeed a logically possible development, but I will not explore it further here, other than to point out my main objections to this type of analysis.

Namely I think that, as Paster (2006) and Bye (2007) amply demonstrate with a wide

range of examples, enough non-optimizing PCA patterns exist to justify the existence of a subcategoriation mechanism by fiat, and any mechanism capable of handling arbitrary subcategorization can handle the optimizing kind as well. I will not recapitulate all of Paster and Bye's examples here, rather I will describe a family of non-optimizing alternations which, to my knowledge, has not been discussed in the suppletion literature.

Consider the case of Wayoro as described in Nogueira (2011, p.145-155). The causative /transitiviser is [mõ-] before a vowel and [õ-] before a consonants.

(53)

causative/transitivized	gloss of the bare form
mõ-ãmõjã	'dance'
mõ-ẽrã	'sleep'
mõ-ɨkara	'cry'
mõ-eɨka	'belch'
mõ-agopka	'warm up'
mõ-atoa	'bathe'
õ-kejtokwa	'laugh (pl.)'
õ-gwea	'move up'
õ-po:riatkara	'age (masc.)'
õ-kodʒikara	'age (fem.)'
õ-pi:tokara	'rest'
õ-paga	'get drunk'
õ-parega	'improve/stay good'
õ-nĩã	'be ashamed'
õ-goa	'mature'
õ-tãnɲdʒora	'get pregnant'

The introduction of an initial [m] does nothing to alleviate the hiatus formed in vowel-initial words. As such it is not clear that any optimization story can be given for this data. This type of V-/CV- prefix allomorphy is widely attested in South American languages, e.g.

in Kanamari (Ishy 2018, p.76-77,164-165, and Anjos Gonçalves da Silva 2011, p.118-120),

Further, enough cases of opaque PCA exist to discourage the applicability of constraints on surface form. We have already discussed the case of Japanese. Moreover it is sufficient to attribute the predominance of seemingly-optimizing PCA to the patterns of sound changes in diachrony, there is no need to further attrbiute it to the grammar. The burden of proof is therefore on those who want to argue in favor of a seemingly redundant optimization mechanism.

5.4.7 Scheer (2016) and melody-sensitivity in PCA

The model of allomorphy described in this chapter allows for PCA to target any feature, as no restriction was put on what features a sticky-end can seek. This goes against Scheer (2016) who argues that PCA cannot be sensitive to melody, defined in his work as the segment content, but can only be sensitive to prosody and sonority, suprasegmental material. Scheer's conceptual argument focuses on the problem for modularity if morphology can see segmental features. Scheer sees his position as following Zwicky and Pullum's (1986) principle of phonology-free syntax, according to which syntax does not use phonological information in its operations. This argument is mostly set in opposition to non-modular OT approaches.

> Now recall that modularity in general and domain specificity in particular hold that vocabulary items that are processed by a given module cannot be read, parsed or understood by another module. In the case of PCA, this means that phonological vocabulary —labial, occlusion and the like that occur below the skeleton— cannot be taken into account by morphological computation, i.e. allomorph selection. Nothing prevents the conditioning of allomorphy by other pieces of phonological representations, though: PCA is free to take into account the output of phonological computation: structure that occurs at and above the skeleton. (Scheer, 2016, p.346)

Scheer examines the empirical data and confirms that nearly every case of PCA in the records involve either the contrast between vowels and consonants as in the Korean case

of 5.3.1 or stress and footing. Other cases largely seem analysable as targeting sonority, e.g. the Swedish allomorphy analysed in 5.3.3 as sensitive to $\pm Approximant$ can be given a generalization as sensitivity to "liquids up" vs. "nasals down" as in (55), and the Kwamera allomorphy analyzed in 5.3.6 as targeting [-hi] with a delinking default can be given the generalization of targetting "mid vowels up" vs. "high vowels down" as in (56).

(54) Korean nominative

$$\overbrace{low > mid > high}^{-ka} > \overbrace{liquids > nasals > fricatives > affricates > stops}^{-i}$$

(55) Swedish Definite Suffix

$$\overbrace{low > mid > high > liquids}^{-n} > \overbrace{nasals > fricatives > affricates > stops}^{-en}$$

(56) Kwamera Perfective

$$\overbrace{low > mid}^{\text{ɨ}n-} > \overbrace{high > liquids > nasals > fricatives > affricates > stops}^{uv-}$$

(57) Nishnaabemwin 3rd conjunct

$$\overbrace{low > mid > high > liquids}^{-d} > \overbrace{nasals}^{-g} > \overbrace{fricatives > affricates > stops}^{-d}$$

A complex pattern that can still be given a prosodic generalization is found in Ikpeng. Campetela (2002, p.155) describes the allomorphy of the second person singular prefix, which takes the form *w-* before [a], *a-* before [Ca-], and [o~ɔ-] elsewhere, i.e. before vowels other than [a] and before CV where V is not [a]. This can be accounted for by paying attention to the sonority of the first two segments: *o-* if both segments are Mid vowels or lower, *w-* if the first segment is Low, and *a-* if the second segment is Low.

And finally for cases that do not look like either prosody or sonority, Scheer proposes that they all can be reanalyzed within the phonology. For instance the Tahitian allomorphy described in 5.3.7 can be reanalyzed as long distance dissimilation[8]. And in cases where the

[8]Paster (2006, p.40) argues against a dissimilation analysis, but the argument is rather weak. There are no comparable prefixes with /f/ in Tahitian that could confirm or disconfirm that this dissimilation is a

alternations do not seem to be general phonological facts of the language, Scheer suggests using the representational power of autosegmental phonology in the way described above in (2) to accomplish moderate amounts of segment replacement within the phonology.

5.4.7.1 Conceptual Problems

A conceptual problem with Scheer's argument is that I do not see how allomorphy based on morphology seeing prosody and sonority is any better for modularity than allomorphy based on seeing any other features. Scheer restricts his version of modularity to the *vocabulary* of a module, understood as the symbols it can read as its input. Scheer takes the lexicon to contain only segmental melody features, and hence only those are the input to the phonology. Prosody and sonority, he claims, are computed on top of the melody and are different. But why is that? Even if sonority is computed and never inputed, it is still computed *within the phonology*. It is a set of symbols used by the phonological module during its computation. For it to be visible by the morphology would require that it not only be a non-input, but that it be an output from phonology to morphology. I fail to see why such a backward interface is desirable in the architecture of language. Further, if there were information sent back from phonology to morphosyntax, it is unclear why PCA would be the only manifestation of it. It does predict the impossibility of labial-movement to spec-CP, but why do we not see C-initial movement to spec-CP, penultimate-stress movement to spec-CP, or polysyllabic movement to spec-CP? Or if this is about visibility by a morphological module distinct from syntax, then why does Scheer invoke Zwicky and Pullum (1986) and the principle of phonology-free *syntax*?

While prosody is *computed*, it is not clear that it is ever *outputed* from phonology. Phonetic evidence for the syllable, a long-desired goal of phoneticians, has failed to yield anything (Ladefoged and Maddieson, 1996, p.282). Prosody has the character of a phonology-internal scratchpad, used for the computation of other things, and then never sent anywhere else. The idea that this most-proprietary set of phonological symbols is the only thing to leak back to feed PCA is architecturally strange. Further, as argued by Carruthers (2006,

general phonological process, so Paster's only argument is the existence of reduplicated forms with multiple [f]'s pointing to the absence of a language-wide ban on [f...f] subsequences. This is insufficient however, as it is well-attested that a phonological process can underapply in reduplicative contexts.

p.59-60) the rejection of *inaccessiblity* of the internal computation of modules defeats the purpose of dividing processing into sub-systems running different algorithms.

Another glaring problem with Scheer's thesis is the mistaken equation of segmental material with what is inputed and suprasegmental material with what is computed. Scheer's modularity argumentation justifies a split as to what can inform PCA by distinguishing inputs to phonology from computed phonology, and the rest of his discussion attempts to equate this split with the segmental vs. suprasegmental split. But these two splits are not the same, and the clearest problem is tone. Although cases of tones that are computable from the melody exist (e.g. the rule of Low Tone Insertion on voiced sonorants in Digo employed above in 3.3.3 as well as by Kisseberth (1984)), tone needs to be stored lexically in many languages, and therefore there is no getting around it being an input to phonology. But there are well-attested cases of PCA sensitivity to such lexical tone patterns. A relatively simple example comes from Hausa plurals as mentioned in Dimmendaal (1987, p.202) and Carstairs-McCarthy (2001, p.115): for bi-syllabic roots the ones with High-Low or Low-High tone patterns take *-una*, and the roots with a High-High pattern take *-ye*[9].

Another example of PCA sensitive to lexical tone is the Ngizim previous reference marker as described by Schuh (1977, p.32-33). This marker takes the form *-wú* after a low-tone monosyllable ending in a long vowel or diphthong, *-ˊw* after *a/i/u*, and *-gú* elsewhere, meaning after consonants, mid-vowels, and diphthongs. This implies some cases where the only determinant is lexical tone (e.g. *dàa-wu* 'the town' vs. *shúu-gú* 'the shit'). There is no sonority or prosody generalization to draw. Note further that Schuh describes two varieties of Ngizim, one spoken by younger speakers behaving as described above (with final [k] assimilating in voicing to *-gú*), and one spoken by older speakers in which final roots with /k/ lose it and behave as vowel-final.

Although these last two examples are not about segmental content, they are definitely about input content, as those tonal melodies need to be pre-specified in the lexicon and are not computed, hence it does not adhere to Scheer's input-vs.-computed dichotomy.

Of course one could imagine a machinery of tone in which all tonal information is computed from segmental melody. This would allow the lexical information to be carried

[9] As for tri-syllabic roots, both authors only say they 'tend' to take the suffix *-ai*, without more discussion.

by lexical items in a non-suprasegmental way while also leaving everything suprasegmental computed. But surely that would be both a hack and circular reasoning. There is no independent justification for putting lexical tone on segments; in fact a lot of the justification behind autosegmental phonology is that tones largely behave independently from segments and are frequently best analyzed as underlyingly floating. A theory of tone in which floating tones are derived from segment-internal tones seems like a step backward. It would also lead to numerous problems, e.g. cases of affixes that have been analysed as floating tones without any segments (e.g. Tiv in Odden 1995) would now need to be re-analyzed with some segment for the tone to come out of.

While it may seem forced to propose this type of computation for tone which Scheer has not proposed, there is a similar conceptual problem is the issue of how sonority information becomes suprasegmental and available for PCA. Surely something that takes the segmental information of $\pm Consonant$, $\pm Approximant$, $\pm Sonorant$ (or their Element Theory equivalent, which is the framework in which Scheer writes) and recapitulates it above the skeleton would be the same type of hack as I described for tone. But Scheer's suggestion is more indirect:

> It is undisputed that syllable structure is a function of two and only two properties: the linear order of segments and their sonority. The sonority of segments is thus legible from above the skeleton by simply looking at syllable structure. (p.349)

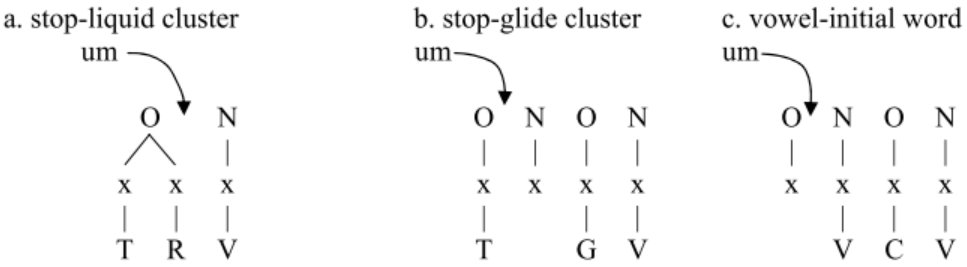
Leaving aside the comment that this is undisputed[10], the claim is straightforward. Scheer does not claim that sonority itself is suprasegmental, rather he posits that sonority informs syllabification, and this syllabification is then visible to PCA.

As an example he discusses an analysis of infixation in a specific variety of Tagalog in which infix placement appears to depend on sonority. In this variety some people infix *-um-*

[10]Not even the existence of syllable structure is undisputed (Samuels, 2009, ch.3). But even if we focus only on pro-syllable analyses, it is arguably indispensable to refer to other features. Consider the syllables of *Atlanta*, as opposed to *apply* and *occlude*. The different syllabification behaviors of [Vt.lV] sequences, in contrast to [V.klV] and [V.plV] in English will have to reference place of articulation in the blocking of [tl] onsets. Despite Scheer's claim that everyone agrees, the proposal that only linear order and sonority are involved is a radical claim that does not seem capable to even describe all the English facts without a radical departure from the traditional account of English syllables.

after the first consonant in stop-liquid complex onsets, but after the whole onset if it is stop-glide. Scheer proposes that if stop-liquid onsets are syllabified differently than stop-glide sequences, e.g. as branching onsets vs. separate onsets, the generalization is statable the syllable level:

(58) Scheer's analysis of Tagalog sonority-controlled affix position



However while this style of analysis works very well in this case where the relevant property is how sonority affects onsethood and how the position of an affix can be stated relative to these onsets, I do not see how it generalizes to all the cases above. The problem is that while sonority may very well *inform* syllabification, syllabification rarely carries *all* the information about sonority. It simply does not follow from the fact that syllables are build using sonority that sonority is legible from the syllable structure. There is no discussion in Scheer (2016) of how this strategy can extend to the cases discussed above in Swedish, Kwamera, or Nishnabemwin aside of dismissing them since their generalization is stateble by reference to sonority.

Consider again the Nishnaabemwin facts discussed in 5.3.4. Recall that the conjunct third person suffix is *-g* after a nasal and *-d* elsewhere. Scheer dismisses this example since the generalization can be made on the basis of sonority, but he gives no indications of how CVCV phonology can actually handle this example. It is unclear what property of syllabification is supposed to make nasals, and nasals alone, syllabified differently from other consonants in final position, both the more sonorous consonants and the less sonorous ones. It is also unclear what exact form those nasal codas could take in Scheer's system: strict CV phonology's only representational degrees of freedom are branching and empty Cs or Vs, and since final /n/ in simple coda can't be any more or less branching than any other Nishnabemwin consonant then it must be an empty CV, or a lack thereof, somewhere

that is causing the allomorphy. But if so then should we not expect more effects than merely conditioning allomorphy? E.g. given that Nishnaabemwin stress treats the end of the word specially, saving final vowels from deletion and counting from the final foot for stress (Valentine, 2001, p.51-55), we might predict some effect of final /n/ on stress, but those have not been reported and in fact sound to me very unnatural.

Similarly the Kwamera facts of 5.3.6 again: the perfective is *in-* before non-high vowels and *uv-* before high vowels and consonants. The same question arises: what principle of syllabification is supposed to syllabify initial high vowels differently from initial non-high vowels?

All in all, Scheer's proposal when it comes to sonority is too hand-wavy to be useful. It is not enough to say that sonority can influence syllabification and that PCA can see that to show that this is indeed a viable strategy. Scheer gives no examples or suggestions for how to translate a sonority generalization into a CVCV syllabification-based analysis.

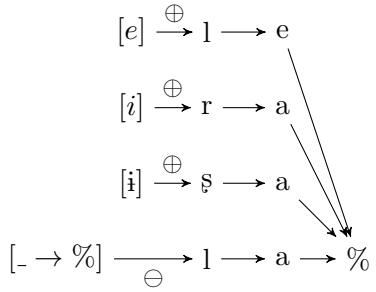
5.4.7.2 Empirical problems

There are also a small number of exceptions to Scheer's generalization, examples of PCA that do not seem to be reducible to prosody or sonority, or re-analysable as complexity in an autosegmental representation.

Consider the Mehinaku genitive as described by Mori (2007, p.255-256) and de Carvalho (2015, p.127). The genitive suffix of Class 1 nouns has four allomorphs: *-le* after final [e], *-ra* after final [i], *-ʂa* after final [ɨ], and *-la* after final [a] or [u]. Carvalho explicitly claims that no single underlying form could derive these allomorphs given our knowledge of Mehinaku phonology, and there are so many segments involved that there is no room in an autosegmental representation for a Floating-Segment-Replacement strategy like that used for Caddo above. The only Mehinaku CV sequences reported to be unattested are *ʂi, *lɨ, *re, *rɨ and *wu (Mori, 2009). This does not seem enough to account for all of the changes even if all four consonants and three vowels were packed together in a string to fight over the same CV. In contrast this pattern is easy to handle in PROP with a form like (59) with

sticky-ends seeking specific vowels.

(59)



A second example that does not fit Scheer's prediction is from Menya (Papuan). Whitehead (2004, p.75-76) mentions that many Menya verb stems have two forms: one 'basic' form found before a consonant other than /q/ and a 'derived' form found before a vowel or /q/. Whitehead is very explicit that these changes are idiosyncratic and do not reflect general processes of Menya. Some of these alternations are relatively small changes, such as *päk* ~ *päs* 'hit/kill', *ma* ~ *me* 'get/have', and others are completely suppletive such as *mi* ~ *nyuä* 'birth', *p* ~ *suä* 'harvest'. Some examples in context are shown in (60). There is no phonological consistency in the forms, e.g. 'tour' ending in [ä] in the basic form and [i] in the derived form, but but 'birth' ending in [i] in the basic form, and [ä] in the derived form, making any derivation based on regular phonological processes hopeless.

(60) Menya Root variations (Whitehead 2004, p.76)

Gloss	Basic root	'they're going to _' _-p-ŋqä-i _-23P/IRR-GOAL-IND	Derived root	'not-_-ing' ma-_-qä NEG-_-DVZR	'we're going to _' _-atu-ŋqä-i _1P/IRR-GOAL-IND
get/have	ma	mapŋqe	me	mämeqä	metuŋque
tour	ikä	ikäpŋqe	iki	mïkiqä	ikituŋque
act	q	qpŋqe	qiy	maqiyqä	qiyatuŋque
hit/kill	päk	päkpŋqe	päs	mapäsqä	päsatuŋque
birth	mi	mipŋqe	nyuä	manyuäqä	nyuatuŋque
harvest	p	ppŋqe	suä	masuäqä	suatuŋque

Another example is from Seri. Marlett (1981, p.58-62) describes the suppletion of the Action/Oblique Nominalizer, which combines both morphological and phonological conditioning. The form of this prefix can be described by following the following rules in this order:

(61) Seri Action/Oblique Nominalizer prefix

1. before the verb /ap/, 'stand': /ʔi-/
   (/i-ʔi-ap/ 3P-NOM-'stand' = 'my standing')
2. before a +low short V or C: ∅
   (/ʔi-∅-emen/, 'my winnowing it')
3. before a passive: /ʔ-/
   (/ʔi-ʔ-a:ʔ-kašni/, 'my being bitten')
4. before a vowel that is +Low or +Back: /y-/
   (/ʔi-y-otx/, 'my arising')
5. elsewhere: /ʔ-/
   (/ʔi-ʔ-ip/, 'my staightening it')

There is a lot that could be said about this pattern of affix , but what is relevant to the discussion at hand are steps 4 and 5: this is a case of PCA sensitive to vowel backness. This means that for any non-passive verb starting with a non-low vowel, vowel backness determines the *y-*/*ʔ-* suppletion.

Seri has multiple very complex patterns of allomorphy, many of which boil down to regular phonology, and a lot of care was given by Marlett (1981) to finding regular rules able to derive these forms, so we can trust that regular Seri phonology is unlikely to be able to derive this. A Floating-Segment-Replacement analysis seems hopeless in light of the fact that sequences of [y] with front vowels and [ʔ] with back vowels are apparently allowed on the surface: e.g. [p-y-i:m], 1SS-DIST-'sleep' (p.20), and [ʔ-oko:-ʔo], 1P-OBJECTNONFUTURENOMINALIZER-'see/saw' (p.57).

Anjos Gonçalves da Silva (2011, p.121-123) describes another example of melody-conditioned allomorphy in the Katukina-Kanamari intransitivizing suffix. This suffix surfaces as *-k* after /u/, *-i* after [-sonorant] consonants and any other vowel, and *-hiK* after [+nasal] segments

(non-nasal sonorants cannot occur in the coda, plus in this positions all non-sonorants neutralize to [kˀ] and all nasals neutralize to [ŋ]).

Another problem can be found in Zulu. Lanham (1953, p.148) and Posthumus (2006, p.128) describe a prefix variously called the copulative or the identificative, which is *ng-* before [a,e,o,u] and *y-* before [i]. There is no language-wide ban of *ngi* or *ya/ye/yo/yu* sequences in the language. This sensitivity to /i/ vs. /u/ cannot be captured with sonority.

Nakanai also poses a challenge. Johnston et al. (1980, p.136 fn.2) mention that the reciprocal/causative prefix has the form *va-* before vowels, [h] and [l], and *vi-* elsewhere. Examples of word boundaries with [i] followed by [l] or vowels or [a] followed by consonants other than [h], [l] are numerous in Johnston et al. (1980) (though admittedly not sequences of [i-h]). Nakanai has another liquid [r] as well as fricatives [v] and [s] hence there is no generalization of [l] and [h] to make in terms of sonority.

A number of additional examples involve small allomorphs or are not fully suppletive and therefore I cannot rule out that my inability to imagine giving them a Floating-Segment-Replacement treatment is due to my lack of imagination and not to a problem of the theory, but in all cases the facts involved seem to be somewhat too complex to really be handled in one autosegmental UR.

One such example is from Witsuwet'en. Hargus (2011, p.229-231) describes the second person singular possessive prefix, which has the form *nj-* before vowels, nasals, [s], and [z], and *n-* otherwise. Before a consonant the form *nj-* further epenthesizes a schwa, *njə-*. Vowels, nasals, and sibilants to the exclusion of other fricatives and [l] cannot be captured in terms of sonority, and this cannot be surmised to a general phonological process as e.g. [n]+vowel and [nz] sequences can occur at other morpheme boundaries with the perfective *(ə)n-*, e.g. [ni-n-in-ye] 'stay/stop'+CNJ-PERF-'sg. go' (p.781,813), [ho-n-zu] AREAL+PERF+'be good' (p.622).

Another case that looks difficult for Scheer comes from Garland and Garland (1975) and their description of the future suffix in Koiali. The future is *-si* after /i/, and *-i* elsewhere, e.g. *hei-si* 'I cut-FUT' vs. *ta-i* 'go-FUT'. Given that /s/ is found after other vowels (e.g. in the suffix *-seleve* 'really' in the manner slot of the verb, *eleg-eve-seleve-holi-holi-n-u* 'see-Pl.Obj.-really-not-not-sing-past') deletion of /s/ after vowels other thant /i/ sounds like a

poor analysis. However I cannot find the data or information about Koiali phonological processes to reject various other hypotheses such as [s] epenthesis in i_i.

Another example is found in Movima. Haude (2006, p.64) describes the allomorphy of the intensifier/phasal aspect marker morpheme which is /uk/ after /a/, /aj$^{\text{ʔ}}$/ after /u/, and in free variation between the two elsewhere, i.e. after /i, e, o/. The sensitivity to /i/ vs. /u/ cannot be accounted for via sonority or prosody alone. However the reason I cannot fully dismiss a Floating-Segment-Replacement analysis here is that the phoneme /j$^{\text{ʔ}}$/ seems to have a very limited distribution, 'usually after the vowel /a/' (Haude, 2006), hence a derivation based on underlying /aj$^{\text{ʔ}}$/ with dissimilation of *a* to *u* after *a* followed by delinking of /j$^{\text{ʔ}}$/ after *u* with re-attachment of a floating *k* is plausible.

Another difficult case of partially suppletive melody-controlled PCA is in Hawaiian. Elbert and Pukui (2001, p.76) describes the Causative/Simulative prefix which has the form *ho-* before a glottal stop followed by a long vowel, *hō-* before a glottal stop followed by a short vowel, *hōʔ* before /i/, *hoʔ* before /e, a, o/ and sometimes /i, u/, and *hoʔo* before any consonant other than the glottal stop. Because all these changes involve length or segments that are either present or absent I cannot fully dismiss a floating segment analysis in which the /ʔ/ and the second /o/ are floating and only attach in certain contexts, but such an analysis would require ad hoc assumptions about ʔ-initial words.

Also difficult is the allomorphy of the Muskogee Patient Agreement markers. Martin (2011, p.168-171) gives the forms of the 1S, 2S, and 1P agreement markers as respectively *ʧa-*, *ʧi-*, and *po-* before consonants and short /i/ and *aʧa-*, *iʧi-*, and *ipo-* elsewhere. This is further complicated by the behavior of the vowel-vowel sequences created by these allomorphs. When the second vowel is /o/ or /o:/, the first gets deleted; when the second vowel is short /i/ or /a/ this second vowel gets deleted; and when the second vowel is long

/i:/ or /a:/, this second vowel gets deleted and the first lengthens.

(62) Muskogee Patient agreement marker 1S prefix

/na:fk/ 'hit'	[ʧa-na:fk-i:-s] 'he/she is hitting me'
/inokk-/ 'be/get sick'	[ʧa-nókk-i:~~us~~] 'I am sick'
/otak-/ 'hug'	[aʧ-óta:k-ís] 'he/she is hugging me'
/anokiʧ-/ 'love'	[aʧa-nokíʧ-i:-s] 'he/she loves me'
/a:faʧk-/ 'be/get happy'	[aʧa-:fáʧk-i:-s] 'I am happy'
/i:lisk-/ 'be/get sulky'	[aʧa-:lísk-i:-s] 'I am sulky'

However an analysis of Muskogee based on prosody and sonority cannot be fully dismissed since the Muskogee vowel system is /i, o, a/, and hence short /i/ can be singled out from other vowels through sonority and prosody alone, but again I do not see how the sonority difference between /i/ and /a,o/ can be reflected at the syllable level in near-minimal pairs like /inokk-/ vs. /amoki/. The forms with short /i/ would need to have some difference at the CV level compared to /a/ and /o/ to drive the allomorphy, but /i/ and /a/ can't be too different either since they behave the same in terms of vowel deletion in contrast to /o/. I do not see how all this information can be packed autosegmentally in a single UR, particularly not if it is meants to follow directly from CVCV-phonology's assumptions.

Another difficult example comes from a Tuvaluan coordinating conjunction described by Besnier (2002, p.152-153) which has the form *kae*, except before initial [k] where it has the form *a*. The natural Floating-Segment-Replacement analysis would involve dissimilation causing delinking of the /k/ of *kae*, however a general delinking of /k/ before /k/ is implausible in Tuvaluan given other examples of syntactically close [kV+k] sequences at the surface. The preposition *ki* can occur before /k/-initial words, *ki kaleve* 'to toddy' (p.175) and the negative marker *seki* that can occur before /k/-initial verbs, *seki kkau* 'NEG join' (p.573). But even if we accept this delinking of /k/ before /k/ across vowels, I do not see how this would easily account for the dropped /e/. If anything in CVCV phonology the delinking of a consonant should open up more vowel slots, this is the whole logic behind

CVCV phonology's approach to compensatory lengthening, but here we have a case in which a delinked consonant causes fewer vowels to surface.

One other problem is found in Aguaruna as described in Overall (2007, p.78). Multiple suffixes of the language have a 'short form' and a 'long form' with idiosyncratic phonologically- or morphologically-conditioned distributions. One in particular is a locative/different-subject suffix, which has the long form *-nĩ* after /i/ or /ɨ/ and *-ĩ* elsewhere. Complicating a phonological analysis, there are multiple examples of morpheme boundaries between a vowel other than [i]/[ɨ] and [n], contradicting a deletion analysis (e.g. with the accusative *-na*: *kamisa-na* 'clothing-ACC', *tayu-na* 'oilbird-ACC'). Further, vowel sequences arising at morpheme boundaries, including [i-i] and [ɨ-i], seem to be resolved with deletion, not epenthesis (e.g. with the declarative *-i*: [puhámi] </puhu-a-mɨ-i/ 'live-IMPVF-2-DECL), complicating an analysis with insertion or docking of a floating /n/.

Another allomorphy pattern that seems difficult to account for with only CVCV mechanics but that I cannot prove is impossible is found in Vitu as described in Van den Berg and Bachet (2006, p.30-31). The nominalizing suffix has three forms: *-aŋa* after /e/, *-ŋa* after /a/ (and one exception in /i/, *hani-ŋa* 'food' from *hani-* 'eat'), and *-a* elsewhere, i.e. after /i, o, u/ (Vitu does not allow closed syllables and all roots end in a vowel, p.12). Van den Berg and Bachet point out that the choice of *-ŋa* over *-a*, can reasonably be attributed the fact that [aa] sequences are not permitted in the language, but it is still a challenge for a Floating-Segment-Replacement analysis as sequences of other vowels and [ŋ] are allowed, making a delinking hypothesis untenable (e.g. *vari-ŋoro-ai* 'sleep' (p.81) with the circumfix *vari-...ai* inflecting intransitives for a plural subject; *vari-kodo-ŋi* 'help each other' (p.80) with *vari-* marking reciprocals on transisitive verbs). And even if the choice of *-ŋa* is explained there remains *-aŋa* after /e/ to explain.

Another difficult case is reported in Kosena by Doreen (1974, p.15-16). Kosena has a set of prefixes which mark the possessor of certain nouns and the object of transitive verbs. The 2nd person non-singular and the 1st person are respectively *t-~tu-~tin-~ti-* and *s-~su-~sin-~si-*. *t-* and *s-* occur before /o/, /aa/, /i/ & /u/, *tu-* and *su-* before /w/, *sin-* and *tin-* before /k/, and *si-* and *ti-* elsewhere. Both the sensitivity to mid vowels /e/ vs. /o/ and the sensitivity to /k/ vs. other stops are a problem for an analysis based on sonority and the

latter is also unlikely to be able to receive a Floating-Segment-Replacement phonological analysis since the normal outcome of nasals followed by stops in Kosena is not deletion but assimilation (p.9-12).

And finally a few more examples that seem to pose a serious problem, but where the data or analysis in my sources is either doubtful or very scant.

One such case which might be complicated for Scheer is the French allomorphy of [œf]~[ø] 'egg' in Swiggers (1985). Contrary to most prescriptive and descriptive sources saying that varieties of French that still distinguish the two have [œf] in the singular and [ø] in the plural, Swigger claims the existence of speakers for whom the allomorphy does not in fact track morphosyntax, but rather the presence of /z/ before it, giving the forms [lezø] 'the eggs', [døzø] 'two eggs', [sizø] 'six eggs', and [dizø] 'ten eggs', but [katʀœf] 'four eggs', [sɛ̃kœf] 'five eggs', [sɛtœf] 'seven eggs', [ɥitœf] 'eight eggs'. This pattern, if indeed it represents a real variety of French, would be a problem for Scheer[11]. One caveat however is that I am skeptical of the existence of this variety. The [œf]~[ø] allomorphy, and plural allomorphies in general, has been in flux in spoken French for centuries and finding people who use either at different times is not difficult. It is very possible that Swiggers is reading too much into what is really free variation or multi-dialectalism.

Another potentially difficult case with too little data to thoroughly trust is found in Ikpeng according to Pacheco et al. (1997, p.39). Pacheco gives a table of the phonological conditioning of possessive prefixes which claims that the third person possessive is *e-* before the forms [-eren-], [-engru-] and [-mtag-], and *i-* before [-amto-], [-laglu-], [-lu-], and [-pun-]. This could be read to mean that the form is *e-* before non-low vowels and nasals, and *i-* before low vowels and other consonants, but with such a poor sample of Ikpeng segments and no discussion of the table in the main text, it is hard to know exactly what classes of sounds are intended by Pacheco. The author's further works, although showing explicit

[11] One alternative for Scheer would be to cpitalize on the fact that there is a commonality among all of these [z]'s, namely they are all liaison [z] plausibly marking the plural. Hence one could conceive of this allomorphy not as phonologically-conditioned by /z/, but morphologically-conditioned by the plural morpheme. This analysis would not be without complication either as it raises the problem of why this [z] is not present in other numerals. In isolation the presence of [z] could be given a lexical explanation in terms of some words having a floating /z/ and others not, but if it is lexical then we lose the potential morphological explanation of the allomorphy, hence the morphological analysis would require to put the complexity of whether /z/ is present or not into the morphosyntax.

focus on the allomorphy of possessive prefixes, focuses entirely on the split between what he calls Series I and Series II, which is irrelevant to *e-*/*i-* as both are Series II. Pachêco et al. (2001) claims in a table that *e-* occurs before consonants followed by [e] or [a], which contradicts the table of Pacheco et al. (1997). Pacheco (2007) has the allomorphy in tables but never mentions it, focusing only on the Series I/II allomorphy. This ambiguity suggests that either Pacheco retracted from his 1997 analysis or that he never had a solid analysis of *e-*/*i-* in the first place.

All of these empirical challenges would need to be addressed for the proposal to have a chance of being true, but the proposal as it is is too hand-wavy to even know how one could go to analyze the above data.

5.4.7.3 Falsifiability Problem

However it remains true that cases of PCA unambiguously sensitive to melody are vanishingly rare. Neither Paster (2006), Bye (2007), nor Nevins (2010) mention any clear case in their surveys of PCA other than the ones Scheer has alternative accounts for like the Tahitian example. Scheer's claim therefore still appears to have some force as a very strong typological tentency. Given, based on the empirical problems of the previous section, that the problem likely is not architectural, it is plausible that external factors of diachrony or learning could better explain it better.

However, one good reason why Scheer's claim is so hard to find counter-examples for is that ultimately it does not really prohibit that many features from participating in PCA: the allowance of all sonority allows vowel height and consonant manner to influence PCA, so all things said and done there are very few things left outside of the predicted typology: voicing, place of articulation, and secondary features are pretty much the only features actually predicted to be impossible triggers of allomorphy. And even when one finds one of those, it is very difficult to completely reject a Floating-Segment-Replacement analysis, because even with its limitations there is still a lot of room for allomorphs in an autosegmental graph, and affixes overwhelmingly tend to be very short in all languages, and they tend to be phonologically similar. Any reasonably short or similar set of suppletive allomorphs can plausibly be fitted together in a string and set to compete over one or two floating CVs.

So the only thing that can fully falsify Scheer's claim is a set of long fully suppletive affixes, sensitive to place of articulation or secondary features. I suspect one of the reason those are rare is simply that they cross-cut so many categories.

5.4.7.4 PROP remains modular

I agree with Scheer (2016) on the fact that standard theories of allomorphy require a morphosyntactic module that reads phonological symbols, and they are therefore anti-modular. I also agree with the argument against a morphosyntax that can see phonology. It is important to maintain the Principle of Phonology-free syntax defended by Zwicky and Pullum (1986). However the solution does not require us to segregate the symbols manipulated by phonology into a set of melody input symbols that morphology cannot see and a set of prosodic and sonority symbols that is allowed to leak back into morphosyntax. PROP offers a different solution: no allomorphy happens outside of phonology whatsoever and vocabulary insertion is done in a completely myopic way. Allomorphs are stored within a single representation and phonology-internal organisation is responsible for selection. Vocabulary-insertion does not need to see any phonological environments because there simply is no conditioned insertion in PROP, there is only conditioned attachment within the phonological module. This achieves the desired modularity without having to stipulate what can be in URs and what can leak back to inform allomorphy.

Chapter 6

Morphologically-Conditioned Allomorphy

Not all allomorphy is phonologically predictable. In some cases allomorphy is sensitive to specific lexical items, as in Morphologically-Conditioned Allomorphy (MCA) or a subcase of it Lexically-Conditioned Allomorphy. This can also be accomplished within the phonological module using the PROP technology we have discussed so far.

This chapter is not intended to be a complete survey of the phenomenon of MCA. The first few examples will exemplify the basic mechanics of how MCA could be handled in PROP, but the main goal is to exemplify advantages of parallel structures for MCA in handling some complicated allomorphy patterns.

6.1 Examples

6.1.1 Romanian stem-allomorphy determining the suffix

This first type of allomorphy is sort of intermediate in that the analysis below is essentially a phononological conditioning analysis, but it appeals to unpredictable properties within the root that we haven't seen yet.

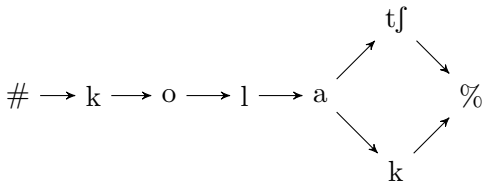
Nevins (2010) discusses the fact that Romanian *k*-final nouns come in two varieties: with or without a *tʃ*-final allomorph. The plural suffix -*i* and the denominal suffix -*i* can only be affixed to *k*-final nouns with a *tʃ*-final allomorph, otherwise the suffixes -*uri* and -*a* are used respectively.

(1) Romanian *k*-final nouns

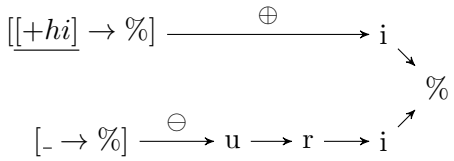
gloss	sg.	pl.	denominal verb
bagel(s)	kolak	kolatʃ-i	ɨŋ-kolatʃ-i, 'to roll up'
'fire(s)	fok	fok-uri	ɨŋ-fok-a, 'to fire up'

This can be handled in PROP with roots containing both allomorphs like (2) and suffixes seeking a [+hi] consonant like (3) (or any feature that captures palatals). The formed optained in (4) will serialize as desired after ⊖-delinking.

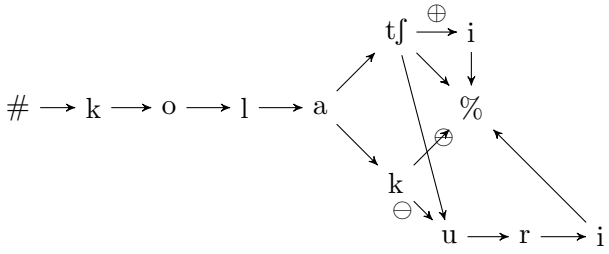
(2) $\sqrt{kolak}$



(3) Romanian plural suffix (incomplete)



(4) *kolatʃ-i*

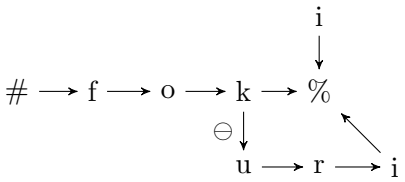


However in the case of roots without this allomorphy in the root like (5), the form will assemble as in (6).

(5) $\sqrt{fok}$

→ f → o → k → %

(6) *fok-uri*



This simple example shows that some of the complexity of allomorphy can be handled by packaging it into morphemes.

6.1.2 English Adjectivizer

Some cases of morphologically-sensitive suppletion are difficult to attribute to the phonological content of roots, even with internal complexities like those assumed for Romanian and Spanish above. For instance English adjectivizers are lexically-conditioned by the roots they attach to without any way to characterize the alternation phonologically.

(7) English adjectivizers

hill	hill-y
moutain	mountain-ous
pole	pol-ar
equator	equator-ial
boy	boy-ish
girl	girl-y
Alps	Alp-ine
Andes	Ande-an

It might be tempting to dismiss this allomorphy by suggesting that *-ous*, *-y*, *-ar*, *-ial*, *-ish* *-ine*, *-an*, *-ic* and other adjectivizers are not allomorphs but different vocabulary items with their own semantic contribution. The choice of words in (7) is intented to argue against this idea in the lines of Isitt (1983). Surely hills are hilly in the same way mountains are mountainous, the poles are polar[1] in the same way the equator is equatorial, boys are boyish in the same way girls are girly, and the Alps are Alpine in the same way the Andes are

[1] As is well known, the *-ar* and *-al* variants are etymologically related and derive from dissimilation in Latin. Examples of English neologisms that do not respect this dissimilation suggest this is not productive in English, e.g. such as *familial* or *dialectal*. the use of *ial* vs. *al* is not productive either, as shown by pairs such as *equatorial*, hence I will not discuss a phonological analysis of *-ar*

Andean. There is no semantic difference between these pairs, there is simply complementary distribution, predictable from the lexical item, and hence allomorphy in the sense of Hockett (1954, §2.7). This is not to deny that some adjective heads are truly separate with their own lexical entry and semantics, e.g. *-able*, but those are not in complementary distribution with the suffixes above and they make a very distinct semantic contribution.

In Distributed Morphology this type of allomorphy is accomplished with exogenous lists in the vocabulary-insertion module. The form *-y* would be inserted in the environment of the roots in the set $\{\sqrt{hill}, \sqrt{girl}, \sqrt{mess}, \dots\}$, *-ous* in the context of roots in the set $\{\sqrt{mountain}, \sqrt{bulb}, \sqrt{courage}, \dots\}$, and so on. This requires dedicated machinery in the vocabulary-insertion module.

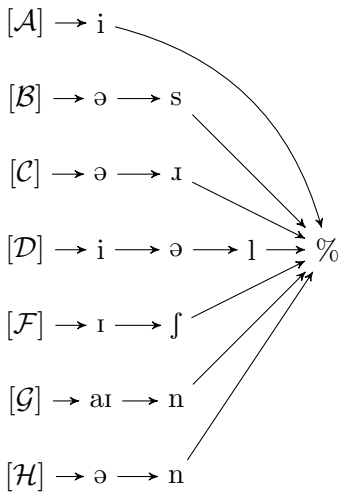
In PROP we could seek to give each form phonological content capable of deriving the correct form in the lines of the Romanian and Spanish analyses above, following the program of Ulfsbjorninn (2016) and Barillot et al. (2018) to get rid of class-driven allomorphy and reduce it to phonological allomorphy through full use of representation. However I will not attempt here to give such an analysis to every case of apparent morphologically-conditioned allomorphy as it would take us too far astray. I aim to discuss the patterns of morphologically-conditioned allomorphy and what PROP can solve about them, not the small details of selection. After all even in absence of diacritic-free analyses, we can account for this kind of allomorphy in PROP as SUF using only the technology we have so far, with alternatives in the underlying form and sticky-ends specifying which one attaches. The use of diacritics in this chapter should therefore not be taken as a strong proposal in favor of arbitrary features and a rejection of the class-eliminativist program. All that is needed is a way to encode the selection within the underlying form, and we have all that is needed for this: the arbitrary features we posited to account for Lakhota infixation in 4.4 and Wolean reduplication in 4.7, except this time encoding not the position of the affix, but which alternant will attach at all. As such the roots will be stored as (8), and the adjectivizer suffix has an underlying form in the ballpark of (9).

(8)

a. $\# \longrightarrow \text{h} \longrightarrow \text{ɪ} \longrightarrow \text{l}_{\mathcal{A}} \rightarrow \%$

b. $\# \rightarrow \text{m} \rightarrow \text{aʊ} \rightarrow \text{n} \longrightarrow \text{t} \longrightarrow \text{ɪ} \longrightarrow \text{n}_{\mathcal{B}} \rightarrow \%$

(9) English adjectivizer (incomplete)

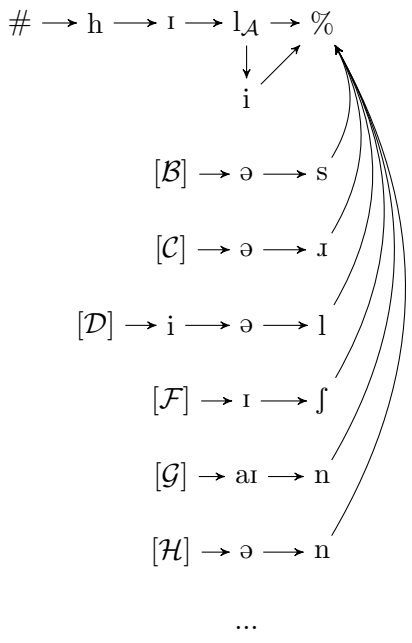


...

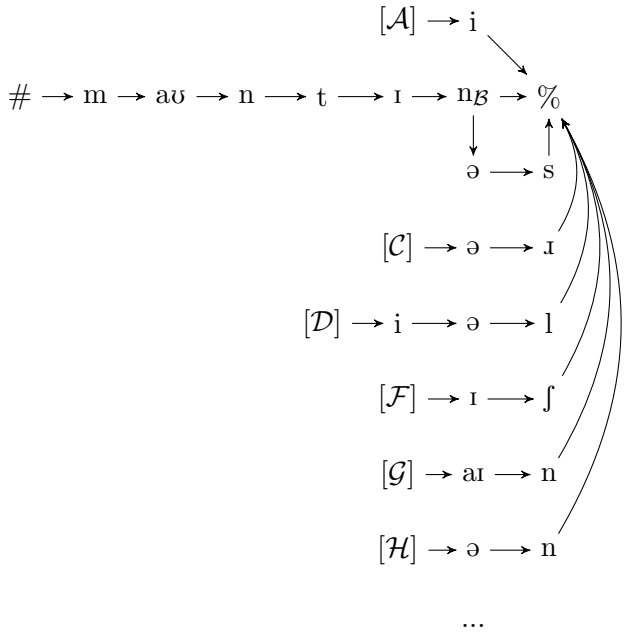
A form like (9) will correctly attach to the forms in (8) because only one sticky-end will

find a segment bearing the correct feature as in (10) and (11).

(10) *hill-y*



(11) *mountain-ous*



There is nothing elegant in this analysis. The claim here is not that the PROP analysis

above is aesthetically superior, but that it can be accomplished within the phonological module using only the technology that was independently argued for to account for infix position and PCA. A superior analysis would ascribe a specific phonological form to the roots above

I would however contend that there is at least nothing *less* elegant about this analysis compared to the alternatives. All theories need to account for this phenomenon through some unpredictable mass of information that must be stored somewhere, and whether we put that information in the form of lists in the vocabulary-insertion module (as in Distributed Morphology) or as features on roots will multiple morpheme-internal alternatives, it will look messy in the end. The advantages of SUF allomorphy are conceptual: in PROP there is no need for powerful contextual insertion mechanisms in a vocabulary-insertion module, allomorphy is done using only pieces of phonology that are independently justified. In PROP allomorphy is done entirely after vocabulary-insertion within the phonology using information stored on affixes.

There is also at least one weak other argument in favor of storing features relating to morphological features on the root rather than as a list: intuitively it is much easier for someone to tell of a specific root whether it is irregular than it is to list all irregular verbs, or all the roots that take a specific allomorph. This is perhaps surprising in Distributed Morphology because there should exist a list of all the roots that take each affix ready in the vocabulary-insersion module, but not in the analysis described here. If the lexical class of a root is information stored in the underlying form on a specific segment, then listing all forms of the same class should be about as hard as listing all the roots with a specific phonological feature, and that is indeed hard.

The rest of this section will discuss other phenomena that can be accounted for with an SUF approach to MCA in PROP.

6.1.3 Allomorphy and Affix position in Nisga'a

The feature mechanics employed so far can account for cases in which there is simultaneously affixes with unpredictable-position and allomorphy at the same time. Sapir (1921, p.62) describes the case of Nisga'a (Nass) in which there are four means of forming the

plural: prefixation, *an'on* 'hand', *ka-an'on* 'hands', *wai* 'paddle', *lu-wai* 'paddles'; vocalic change, *gwula* 'cloak', *gwila* 'cloaks'; suffixation, *waky* 'brother', *waky-kw* 'brothers'; and reduplication, *gyat* 'person', *gyigyat* 'people'.

In PROP, this requires us to use arbitrary features which serve double function indicating both the choice of allomorph and its position. The roots would look like (12).

(12) Nisga'a Roots

a. $\# \rightarrow a_{\mathcal{K}} \rightarrow n \longrightarrow o \longrightarrow n \longrightarrow \%$

b. $\# \rightarrow w_{\mathcal{L}} \rightarrow a \longrightarrow i \longrightarrow \%$

c. $\# \rightarrow gw \rightarrow i_{\mathcal{F}} \longrightarrow l \longrightarrow a \longrightarrow \%$

d. $\# \longrightarrow w \longrightarrow a \succ ky_{\mathcal{KW}} \succ \%$

e. $\# \succ gy_{\mathcal{R}} \rightarrow a \longrightarrow t \longrightarrow \%$

Finally an affix like (13) sensitive to those features will attach to the forms just as

desired, forming the words in (14) (ignoring all the parts dangling from # and %).

(13) Nisgha Plural affix[2]

$$\# \longrightarrow \mathrm{q} \longrightarrow \mathrm{a} \longrightarrow [\mathcal{K}]$$

$$\# \longrightarrow \mathrm{l} \longrightarrow \mathrm{V} \longrightarrow [\mathcal{L}]$$

$$[\_ \rightarrow [\mathcal{F}]] \rightarrow \mathrm{u} \rightarrow [[\mathcal{F}] \rightarrow \_]$$

$$[\mathcal{KW}] \longrightarrow \mathrm{kw} \longrightarrow \%$$

$$[\mathcal{R}] \longrightarrow [\mathcal{R}]$$

(14)

a. $\#$ → a$_{\mathcal{K}}$ → n → o → n → %, with k → a

b. $\#$ → w$_{\mathcal{L}}$ → a → i → %, with l → V

c. $\#$ → gw → i$_{\mathcal{F}}$ → l → a → %, with u

d. $\#$ → w → a → ky$_{\mathcal{KW}}$ → %, with kw

e. $\#$ → gy$_{\mathcal{R}}$ → a → t → %

[2]Tarpent (1983, p.130) notes that the prefixed allomorph is *lV-* which appears with different vowels depending on the stem according to what she calls the Vowel Specification rule: [ə] before [ʔ], [a] before [C̄], [u] before C$^{\mathrm{w}}$, ∅ before [l], and [i] elsewhere. It is not clear whether this assimilation is regular for Nisga'a phonology or if it should be encoded as PCA, but as it is phrased as a rule I omit it from (14).

As we can see PROP has no difficulty accounting for all sorts of irregularities in the location and form of allomorphs.

Note however that the vowel replacement in (14-c) is accomplished by adding a segment parallel to another. This is perhaps a problem: I am assuming that this particular scenario in which a morpheme introduced as segment in parallel to another it is not compatible with, the added segment can circumvent the original one rather than add to it, which does not follow from the assumptions we have proposed so far and therefore needs to be seen as one more assumption of our system. This assumption was already used in multiprecedence, within reduplication to account for fixed segmentism in which one copy has some internal segments replaced by another (McClory and Raimy, 2007), and outside of it to account for subtractive morphology (Gagnon and Piché, 2007). I hope to be able to derive this assumption from simpler axioms in future research.

All I can say about this assumption is that it captures the intuition of Hockett (1954, §4.2) who leaned towards an analysis of *took* as a /t...k/ allomorph of *take* and an infixed allomorph /u/ of /ed/, over analyses with portmeanteau morphemes, zero morphemes, or a /u/</ej/ replacive process. This also captures the intuition behind the terminology of Wallis (1956) who described replacive morphology as *simulfixation* (a slightly different usage of the term than the one mentioned in chapter 3 due to Hocket) .

6.1.4 Lexically conditioned masculine marker in Catalan

Consider the masculine suffix in Catalan discussed by Nevins (2010). The affix has two allomorphs: -*u* and -∅, but verbs that normally take the null affix still surface with -*u* in

the plural, where otherwise a sequence of two [s]'s would occur[3].

(15) Catalan masculine

	sg.	pl.	Gloss
a.	gɔt	gɔt-s	'glass(es)'
b.	mos-u	mos-u-s	'lad(s)'
c.	gos	gos-u-s	'dog(s)'

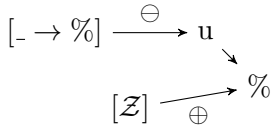
The masculine allomorphy of (15-a-b) can be accounted in PROP with roots like (16) and a masculine affix like (17). The zero affix will attach to roots stored with a [$\mathcal{Z}$] feature that will de-link the /-u/, and otherwise only /-u/ will attach.

(16) $\sqrt{gɔt}, \sqrt{mos}$

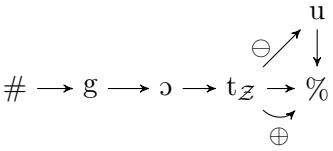
a. $\# \longrightarrow \mathrm{g} \longrightarrow \mathrm{ɔ} \longrightarrow \mathrm{t}_{\mathcal{Z}} \rightarrow \%$

b. $\# \longrightarrow \mathrm{m} \longrightarrow \mathrm{o} \longrightarrow \mathrm{s} \longrightarrow \%$

(17)

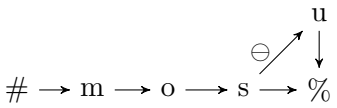


(18) *gɔt-∅*



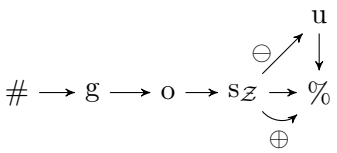
[3]This is, at least, the commonly cited analysis. I see no reason a priori why this pattern could not be accounted for with allomorphy in the plural affix, *-us* after /s/ and *-s* elsewhere leading to accidental partial homophony with the masculine marker. I will however trust the common analysis that the [u] in *gosus* does indeed mark the masculine rather than being part of the plural.

(19) *mos-u*



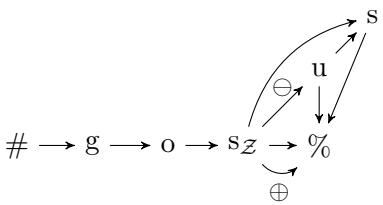
But to account for the behavior of (15)[c] we need two things. First we need a [$\mathcal{Z}$] feature so that the singular form can appear with the zero allomorph as in (20).

(20) *gos-∅*



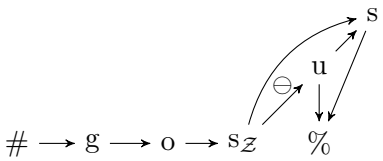
But in the plural the presence of the second /s/ must force the /u/ allomorph to surface. After attaching the plural we get a form like (21) with the /s/ following all segments that precede %. I propose a rule like (22) applying *before* ⊖-delinking. Multiple rules are plausible, as long as it has the effect of delinking the link bearing ⊕. The resulting graph is in (23), and ⊖-delinking does not apply, resulting in the desired surface form *gos-u-s*.

(21) $\sqrt{gos} + u + s$



(22) If there is an /s/ that precedes another /s/, de-link any path from that first /s/ to %.

(23) *gos-u-s*



We will return to phonological operations affecting graphs in chapter 9.

6.1.5 Final Consonants in French Adjectives

French adjectives tend to have a C-final form in the feminine and a masculine form without that final consonant. Adverbial forms with *-ment* are uniformly formed from the 'feminine' allomorph. A traditional explanation of this fact makes use of a final consonant deletion rule and a feminine suffix in the form of a vowel that bleeds the deletion before being deleted in turn. Such a derivation would like like (25).

(24) French regular adjectives

f.	m.	adv.	gloss
fos	fo	fosmã	false,falsely
lãt	lã	lãtmã	slow,slowly
ørøz	ørø	ørøzmã	happy,happily
blãʃ	blã	blãʃmã	white,whitely

(25) Traditional derivation

	f.	m.	adv.
UR	fos+ə	fos+∅	fos+əmã
C>∅/_%	—	fo	—
ə>∅	fos	—	fosmã
SR	fos	fo	fosmã

Booij (1997) remarks that this traditional explanation is insufficient to explain the whole set of facts, in particular the fact that even in the case of irregular pairs it is the feminine

form that is used for adjectives.

(26) French irregular adjectives

f.	m.	adv.	gloss
bɛl	bo	bɛlmã	beautiful, beautifully
sɛʃ	sɛk	sɛʃmã	dry, dryly
vjɛj	vjø	vjɛjmã	old, oldly

The fact is therefore more appropriately viewed as selection for the 'feminine' form, rather than as a regular derivation from a root. French Adjectives have two forms existing independent of gender, and different contexts select one or the other. This type of fact is what leads Booij to argue in favor of allomorphy operating over paradigm slots, and to posit a morphomic level of generalizations that are neither lexical, nor syntactic, nor phonological.

However the analysis of allomorphy we have used so far allows us to analyse the facts of French adjectives entirely within the phonology with all the complexity limited to inside the lexical items. One thing to note is that whether the final consonant of the feminine is present in the masculine or not is unpredictable, as for every consonant that can drop in the masculine an example can be found of an adjective where that same consonant is present in both the feminine and the masculine as demonstrated in (27). The selection can therefore be neither a phonological process nor a phonological conditioning without assumptions about underlying forms as radical as what I am about to propose. The information for how to derive the 'masculine' forms from the 'feminine' one must therefore be arbitrarily known

for each root.

(27) Variable and invariable French adjectives

f.	m.	gloss
sɛʁtɛ**n**	sɛʁtɛ̃	'certain'
ʒo**n**	ʒo**n**	'yellow'
vjolɛ**t**	vjolɛ	'violet'
ipokʁi**t**	ipokʁi**t**	'hypocrite'
gʁã**d**	gʁã	'tall'
ymi**d**	ymi**d**	'humid'
gʁo**s**	gʁo	'big'
mɛ̃**s**	mɛ̃**s**	'thin'
gʁi**z**	gʁi	'gray'
ʁo**z**	ʁo**z**	'pink'
blã**ʃ**	blã	'white'
lu**ʃ**	lu**ʃ**	'fishy, suspicious'
ʒãti**j**	ʒãti	'kind'
paʁɛ**j**	paʁɛ**j**	'same'
lɔ̃**g**	lɔ̃	'long'
bɛ**g**	bɛ**g**	'stuttery'
leʒɛ**ʁ**	leʒe	'light'
fjɛ**ʁ**	fjɛ**ʁ**	'proud'

I therefore propose that French adjectives come pre-specified with features marking the end of each allomorph and different suffixes pick out one of those. A variable adjective would have a form like (28), an invariable adjective would have a form like (29), and a suppletive form would look like (30).

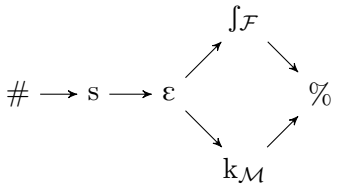
(28) $\sqrt{fos}$

$$\# \longrightarrow \mathrm{f} \rightarrow \mathrm{o}_{\mathcal{M}} \twoheadrightarrow \mathrm{s}_{\mathcal{F}} \rightarrow \%$$

(29) $\sqrt{ʒon}$

$$\# \longrightarrow ʒ \longrightarrow \mathrm{o} \twoheadrightarrow \mathrm{n}_{\mathcal{F},\mathcal{M}} \twoheadrightarrow \%$$

(30) $\sqrt{s\varepsilon(k/\int)}$



Affixes are simply sensitive to these features and will select them appropriately. The feminine affix simply picks the segment bearing an $[\mathcal{F}]$ features, and the masculine affix picks the segment bearing an $[\mathcal{M}]$. The adverbalizer also picks out the segment bearing $[\mathcal{F}]$.

(31) French Feminine affix

$$[\mathcal{F}] \rightarrow \%$$

(32) French Masculine affix

$$[\mathcal{M}] \rightarrow \%$$

(33) French adverbalizer

$$[\mathcal{F}] \rightarrow \mathrm{m} \longrightarrow \tilde{\mathrm{a}} \longrightarrow \%$$

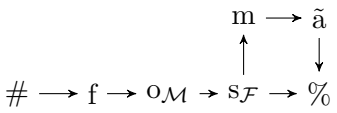
A sample of complex forms follows.

(34) *fos* 'false' f.

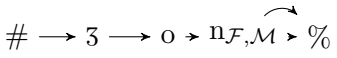
$$\# \longrightarrow \mathrm{f} \rightarrow \mathrm{o}_{\mathcal{M}} \rightarrow \mathrm{s}_{\mathcal{F}} \overset{\frown}{\rightarrow} \%$$

(35) *fo* ‘false’ m.

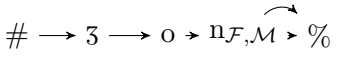
(36) *fosmã* ‘falsely’



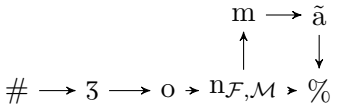
(37) *ʒon* ‘yellow’ f.



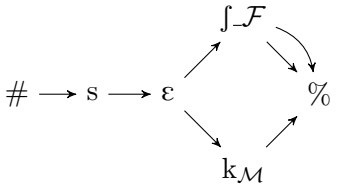
(38) *ʒon* ‘yellow’ m.



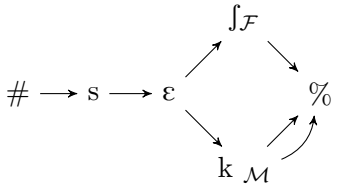
(39) *ʒonmã* ‘yellowly’



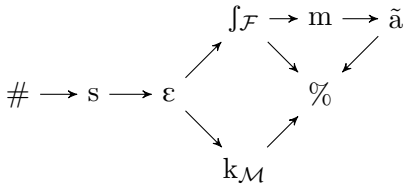
(40) *sɛʃ* ‘dry’ f.



(41) *sɛk* 'dry' m.



(42) *sɛʃmã* 'dryly'



This analysis shows some conceptual advantages of doing allomorphy with features on the roots rather than with lists roots that participate in some process. If this were done in Distributed Morphology the list of environments requiring to insert the 'feminine' or 'masculine' forms or to perform a readjustment rule would have to list the same list of roots multiple times. But certain classes of segments recur throughout a language's morphology, making information storage in the root much more economical. The Feature [$\mathcal{F}$] in the analysis above does not only serve as target for the feminine, it also serves as target for the adverbalizer and in verbalization, thus performing double or triple duty. The feature [$\mathcal{M}$] also has other functions, as the 'masculine' is the form called for in adjective-noun compounds, against expectations from agreement or the semantics of gender, e.g. *grand-père* [gʁã-pɛʁ], 'grandfather', but also *grand-mère* [gʁã-mɛʁ], 'grandmother', and not *[gʁãd-mɛʁ]. The plausibility of these features on the UR is much reinforced if they are reused multiple times in word-formation.

This entails that unlike analyses that take the two forms to be different affixes marked for different gender, the theory proposed here suggests that the two forms are part of a single morpheme unspecified for gender. In that it therefore resembles the analysis in Lamarche (1996).

6.1.6 Hungarian bidirectionally-conditioned allomorphy in Plural Possessives

Another way in which the fact that allomorphy is not fully settled at insertion can manifest itself is by allowing for allomorphy to be conditioned by material inserted later in the derivation, a pattern of allomorphy often termed *outward sensitivity*.

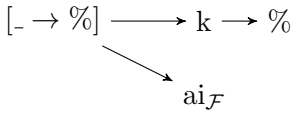
Embick (2010, p.44) discusses the case of the Hungarian plural when it co-occurs with the possessive. The plural surfaces as [-Vk] in isolation, but as [-(j)ai] with the possessive.

(43)

sg.	sg.-1sPoss	pl.	pl.-1sPoss	gloss
ruha	ruhá-m	ruhá-k	ruha-ái-m	'dress'
kalap	kalap-om	kalap-ok	kalap-jai-m	'hat'
ház	ház-am-	ház-ak	ház-ai-m	'house'

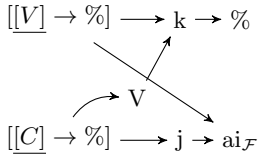
In PROP the analysis of this phenomenon simply follows from defining each of the parts: the plural needs to store both allomorphs, and the possessive needs to select one of these allomorphs if it is available. The plural and 1s.poss look like (44) and (45) respectively[4].

(44) Hungarian plural suffix

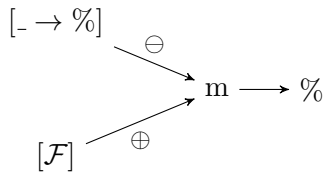


[4]These graphs takes for granted that the harmonic vowel in the post-consonantal [-Vk], [-Vm] and the [j] in [-jai] are epenthetic. Although I am not aware of any explicit claim to the matter, the former process has an independent justification: Vago (1976, p.259-260) justifies an analysis with epenthesis breaking word-final clusters e.g. /bokr/ >[bokor] 'shrub', /tykr/ >[tykør].

In the worst case scenario, if neither of these epenthesis rules is justified and the alternations need to be analysed as PCA based on V- vs. C-final selection, the graphs can be made to convey this, e.g. the plural can instead be represented as the following:

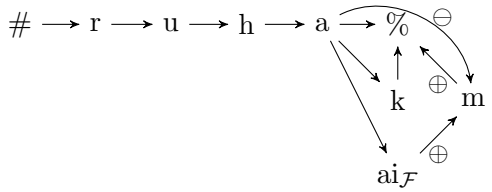


(45) Hungarian 1s.poss



The plural therefore contains a regular [k] part and an [ai] that cannot be pronounced unless something else finds its [$\mathcal{F}$] feature. And the possessive is normally a regular suffix attaching after the last segment, unless it finds an [$\mathcal{F}$] feature. When the two affixes co-occur we get the graph in (46). Again we must assume as in 6.1.3 above that the more recently added links can circumvent others when put in parallel.

(46)



This analysis shows another advantage of delayed allomorph selection, namely it allows for affixes inserted later in the derivation to influence allomorphy of material inserted earlier.

6.1.7 French preposition+article forms

Another example of morphemes added later in the derivation affecting the allomorphy of the ones added prior to them comes from a well known phenomenon of French morphophonology: the suppletive forms of some prepositions with definite articles. Descriptively, it causes us to find *du*, *au*, *des*, and *aux* where **de le*, **à le*, **de les*, **à les* (respectively 'of the.m.sg.', 'to the.m.sg.', 'of the.pl', 'to the.pl') would be expected based on the independent preposi-

tions and articles.

(47)

preposition	#	f. V- 'sword'	f. C- 'soup'	m. V- 'donkey'	m. C- 'dog'
∅	sg.	l'épée	la soupe	l'âne	le chien
	pl.	les épées	les soupes	les ânes	les chiens
à 'to'	sg.	à l'épée	à la soupe	**à l'**âne	**au** chien
	pl.	aux épées	aux soupes	aux ânes	aux chiens
de 'to'	sg.	de l'épée	de la soupe	**de l'**âne	**du** chien
	pl.	des épées	des soupes	des ânes	des chiens

The four forms in bold are where an interesting interaction between phonology and allomorphy emerges. The masculine determiner *le* has an allomorph *l'* before vowels, and the generalization is that sequences of *à/de* and this determiner are replaced by *au/du* if and only if the form *le* would be expected.

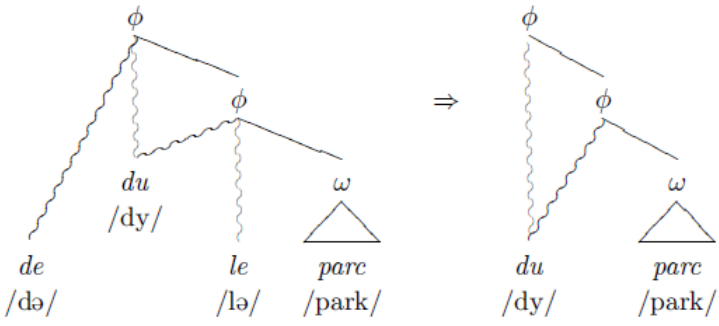
Zwicky (1987) explains the problem posed by these forms: if elision of *le* to *l'* is phonological and the 'fusion' (in Zwicky's terms) into *du* is morphological, then French is demonstrating a phonological operation is taking precedence over a morphological one. Embick (2007, 2010, p.63-) further points out that it is difficult even if both operations are morphology-internal, as in Distributed morphology the Lowering responsible for the preposition going to the determiner is supposed to be an early morphological operation, and the Article Cliticization is dependent on linearization which in his model should happen after lowering.

This difficulty is what leads Bye and Svenonius (2010) and Svenonius (2012) to abandon the strict modular and derivational assumptions of Zwicky and Embick and posit an analysis in which constraints on minimizing exponence are ordered in the same constraint ranking as phonological constraints. They propose competition taking place over a representation containing multiple competitors for insertion, including ones differing in span. Candidates for insertion are illustrated in (48) with squiggly lines connecting each morpheme to its

insertion site. A constraint *Struct penalizing candidates with more exponents favors the portmanteau spell-out of *du* over the individual spell-out of *de* and *le*, as in (48). The blocking of *du* by *de l'* is analyzed as a case of the phonological constraint Onset ranked above *Struct yielding (49).

(48) *du parc* (, p.)

a.

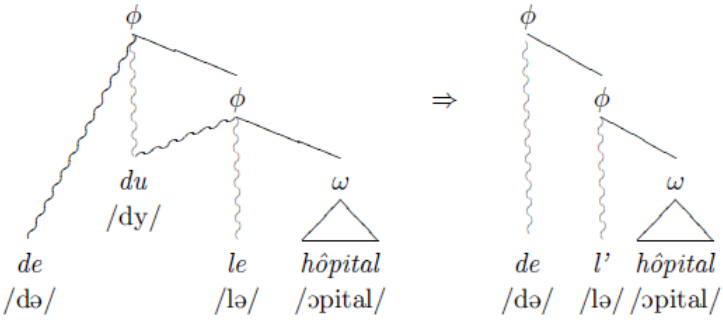


b.

/{də lə, dy} park/	Ons	No-Coda	*Struct	Parse-V	*ə
a. ☞ dy.park		**	*		
b. də.lə.park		**	**!		**
c. dəl.park		***!	**	*	*

(49) *de l'hôpital*

a.



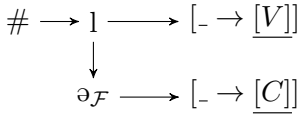
b.

/{də lə, dy} ɔpital/	Ons	No-Coda	*Struct	Parse-V	*ə
a. dy.ɔ.pi.tal	*!	*	**		
b. də.lə.ɔ.pi.tal	*!	*	***		**
c. ☞ də.lɔ.pi.tal		***	***	*	*

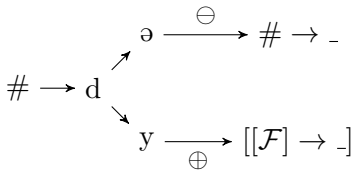
This analysis is highly anti-modular, as it posits a single representation on which morphosyntactic features and phonological material cohabit so as to be compared by a constraint ranking. The PROP analysis of this phenomenon is not in terms of portmanteau,

but rather takes advantage of the representational power of directed graphs to have one morpheme 'by-pass' another. The masculine determiner needs to look as in (50). The prepositions *de* and *à* look as in (51) and (52), respectively.

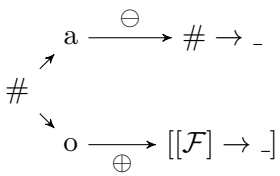
(50) French Masculine determiner



(51) preposition *de*



(52) preposition *à*

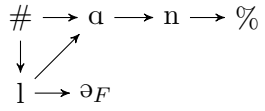


Here the *du* and *au* forms are taken to be allomorphs of the preposition. The replacement of *le* is done with sensitivity to the feature [$\mathcal{F}$] on the schwa of *le*: the sticky-end linked to /y/ always attaches to a segment following this schwa, and hence it causes the graph to by-pass the *le* completely. But crucially, because the schwa only attaches to word-initial consonants, the *du* and *au* morphemes will only find a segment following [$\mathcal{F}$] in C-initial

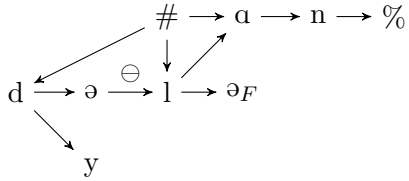
words, and hence the by-pass of the *le* will happen only in C-initial words, as desired.

(53) *de l'âne*

a.

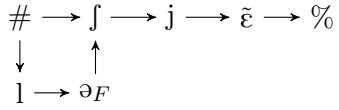


b.

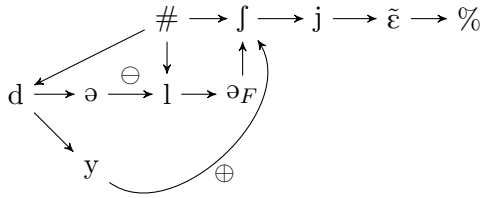


(54) *du chien*

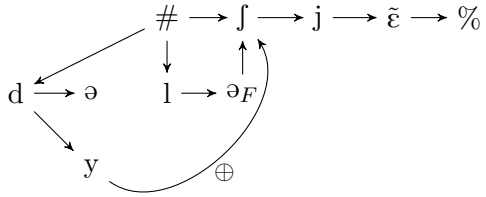
a.



b.



c.



This analysis offers an alternative to the two main theories used to analyze sequences of syntactic terminals surfacing with a single morpheme: contextual zero-allomorphs and portmeanteaux. Zero-allomorphs have always been treated with a lot of suspicion in morphology. Hockett (1954, §4.2) cleverly criticizes the analysis of *took* as an allomorph of *take* with a zero-allomorph of /ed/ by pointing out that the same rules that allows such an analysis would just as easily allow for *took* to be an allomorph of /ed/ accompanied by a zero-allomorph of *take*. Matthews (1974, p.123) called analyses with zero-allomorphs

'desperate'.

Portmanteaux have often been received more favorably, but they require a system of vocabulary insertion capable of handling variable size inputs, which adds complexity to the vocabulary insertion system.

The PROP alternative here utilizes only the machinery elsewhere needed for phonology-internal purposes while keeping the vocabulary-insertion in the form of a single mapping from terminals to phonological URs without any comparison, competition, or context-sensitivity needed. Morphemes can fail to show overt phonetic effects, not because they are contextually zero, but because they were phonologically 'by-passed'.

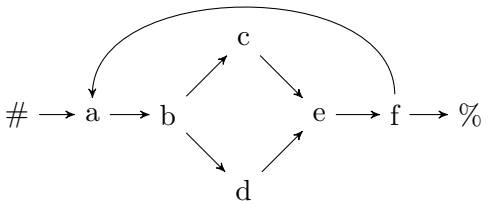
Chapter 7

Interaction of parallel structures with reduplication

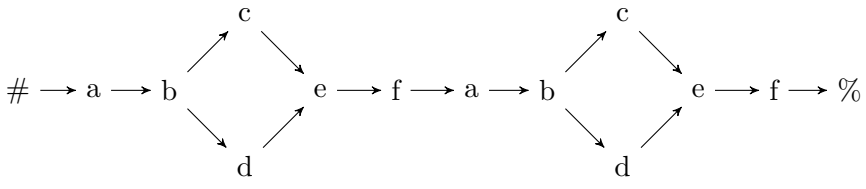
In this section we will take for granted the parallel structures of the previous chapters and discuss further interesting interactions with reduplication so as to fully tie the PROP program into the Multiprecedence analysis of reduplication.

I will not offer a full-fledged 'linearization' or 'serialization' algorithm (now a misnomer, as the final structure is no more taken to be linear or serial) in this thesis. I will simply assume a few basic interactions between parallel structures. For instance I want to posit that structures like (1) would be sent to the articulators as in (2). Essentially parallel structures normally surface in both copies.

(1)



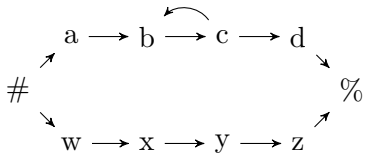
(2)



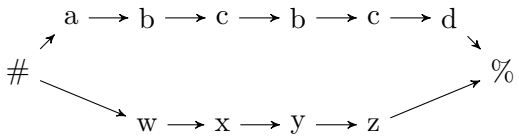
And I want to posit that (3) is resolved as in (4). Essentially reduplication is resolved

locally when it can, without interfering with parallel structures.

(3)

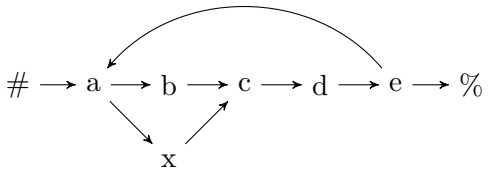


(4)



I also need to borrow an assumption for previous Multiprecedence analyses such as McClory and Raimy (2007), namely that adding a parallel segment can result in replacement in a single copy, as if the form traverses one arc in one copy and one in the second, such that (5) surfaces as one of the forms in (6) (subject perhaps to parametrization). This is similar to an assumption we had to make in §6.1.3.

(5)



⇝ abcde-a**x**cde

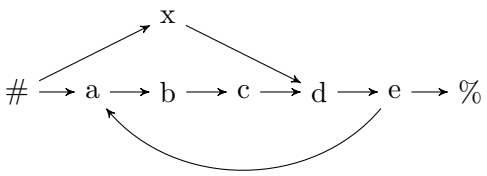
OR

⇝ a**x**cde-abcde

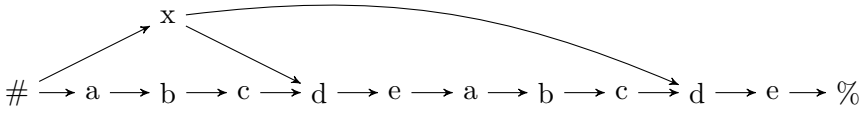
And finally, and least intuitively, I posit that forms such as (6) are resolved as in (7). The logic is simply that the X is not involved in the reduplication, and after the reduplication is resolved X is left precededing both copies of what it was originally set to precede with the net effect that it is restricted to the first. I will omit the redundant arc to the second

copy in the rest of this chapter.

(6)



(7)



The rest of this chapter will discuss a number of cases in which reduplication interacts with parallel material, or multiple lines of parallel material interact with each others.

7.1 Tuvan vowel and harmony overwrite in reduplication

Harrison and Raimy (2004) describe reduplication in Tuvan and give an account using Multiprecedence. Tuvan has multiple reduplication patterns, but I want to focus on total reduplication with vowel overwrite. This construction has the semantics of 'X or something like X'. As seen in (8) the generalization is that the underlying vowel is overwritten with [a] in the second copy, unless it is /a/, in which case the second copy gets [u]. The forms in /a/ introduce some irrelevant complexity that I will not address. I take for granted that a

dissimilatory phonological rule prior to serialization can handle it.

(8) Tuvan total reduplication

simple form	reduplicated form	gloss
nom	nom-nam	'book'
er	er-ar	'male'
is	is-as	'footprint'
ög	ög-ag	'yurt'
süt	süt-sat	'milk'
qɨs	qɨs-qas	'girl'
xol	xol-xas	'hand'
at	at-ut	'name'
aar	aar-uur	'heavy'

An interesting side effect of this reduplication pattern is how it affects Tuvan vowel harmony. Tuvan has a backness and rounding harmony, and so in cases where a front vowel is overwritten with [a] we have a change in backness. Disyllabic forms show that vowels after this [a] pattern with back vowels. Unfortunately Harrison and Raimy (2004) do not discuss harmony on suffixes.

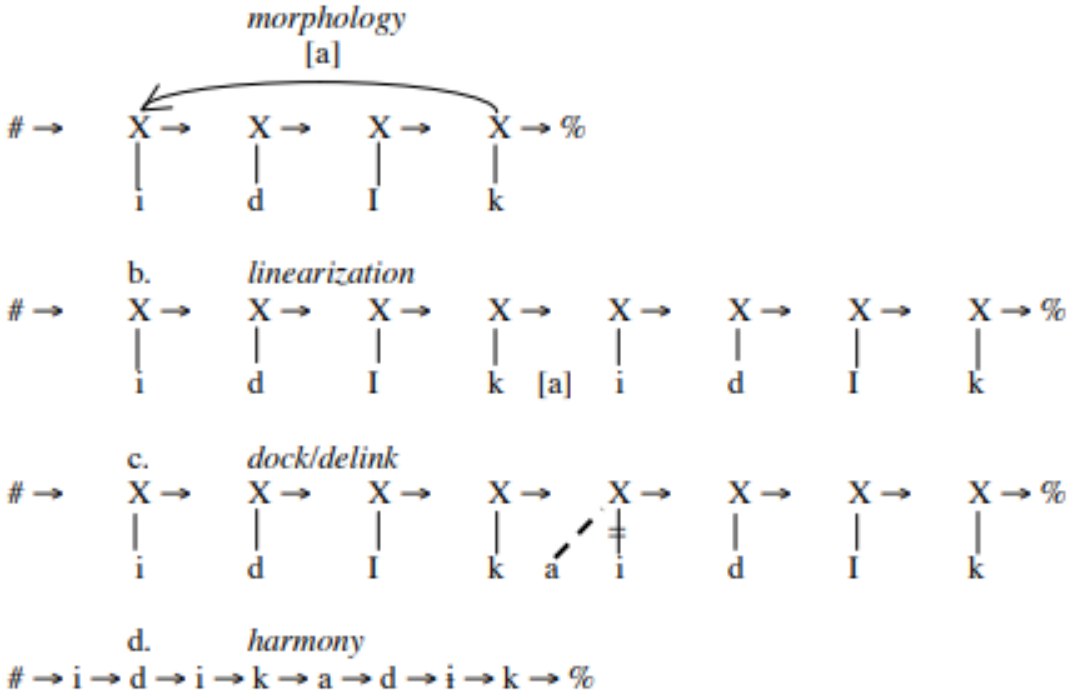
(9)

simple form	reduplicated form	gloss
idik	idik-adɨq	'boot'
inek	inek-anaq	'cow'
nomdʒuur	nomdʒuur-namdʒɨɨr	'read'

Harrison and Raimy (2004) offer an analysis in terms of multiprecedence. They posit that the precedence loop from the last to the first segment comes with a floating [a] which overwrites the first vowel of the second copy, and that vowel harmony operates on that

representation. Their analysis is copied in (10).

(10)

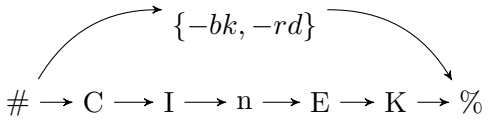


There are some issues with this analysis. Some are minor like the omission of the effect of backness harmony on /k/>[q]. But a bigger issue is the idea of a precedence link accompanied by a floating segment parallel to it. It is clever, but it certainly feels to me like an abuse of notation. It treats the arrow as an object in the representation with respect to which a segment can be parallel, rather than a notation for the organization itself. There is certainly no way to represent this in the ordered pair notation I took as primary in ch.2.

But all these issues could be remedied. What I want to do instead is propose a full PROP analysis, in which vowel harmony is not a separate operation, but -as proposed in chapter 3- accomplished via parallel features. First consider a disyllabic root like (11), where /I/, /E/, and /K/ are underspecified in backness and the first two also in rounding.

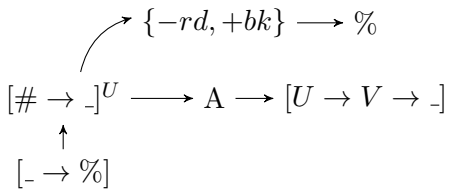
/C/ is an empty consonant needed for the analysis to work.

(11) $\sqrt{inek}$



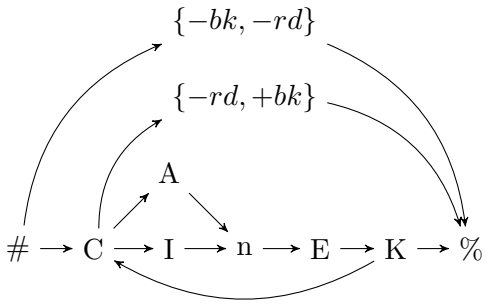
The affix we are discussing must do three things to this root. First it must cause reduplication, hence it will add a path from the last segment to the first segment. Second, it must overwrite a vowel, so it must add a vowel in parallel to that of the root. Third, it must add a new harmonic feature bundle $\{+bk, -rd\}$ in parallel to the form. I posit a single affix with the content in (12).

(12) Tuvan 'X or something like X' affix



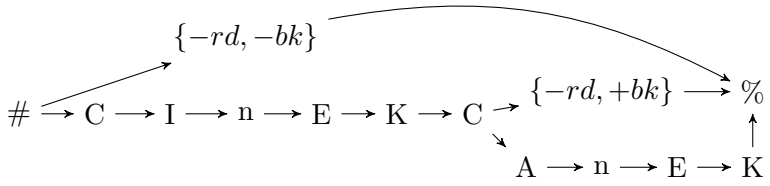
When affixed to (11) this will yield (13).

(13) *idik-adıq*



(13) will serialize as in (14).

(14) Serialization of (13)



Surface: [inekaniq]

This final form is exactly what we want. The Nesting Principle takes care that $\{-rd, +bk\}$ is realized on the second copy and beyond, leaving $\{-rd, -bk\}$ only on the first copy, and the overwriting vowel surfaces in the second copy.

7.2 Tone remaining on a single copy in Yao

Downing et al. (2005, p.3) describe the case of Yao verbal reduplication in which the iterative is marked with total reduplication, but with the second copy lacking any tone. (15) gives examples in the infinitive marked with *ku-*.

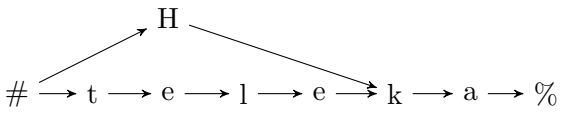
(15)

Infinitive	Gloss	to X repeatedly
ku-téléka	'to cook'	ku-téléka-teleka
ku-wómbóka	'to save'	ku-wómbóka-womboka
ku-súlúmunda	'to sift'	ku-súlúmunda-sulumunda

This is straightforward if roots have the form in (16) with the high tone not reaching the end, which doubly makes sense given that a) in trisyllabic forms the tone only extends to the first two syllables, and b) the final *-a* is probably a suffix that Downing did not gloss

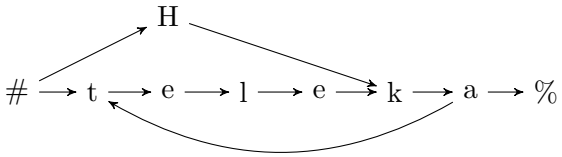
as such.

(16) $\sqrt{cook}$

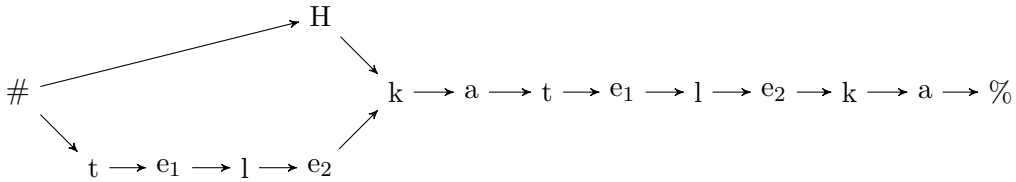


The reduplicated form would get an arc as in (17) and serialized as in (18). I am here assuming that since the H tone precedes /k/ and reduplication picks back up at a point after the start of H, the tone will find itself on a single copy. A more detailed algorithm would be necessary but this seems like the intuitive resolution to me.

(17)



(18) Final form of (17)



The resulting graph is what we want, with the H tone stretching only over the first copy and the second one without tone.

7.3 Tone-overwrite and semi-parallelism in Hausa

Newman (1986) describes two types of affixes in Hausa: Tone Integrating affixes (TIA) that overwrite the tone of the stem they attach to, and Tone Non-Integrating affixes (TNI) whose tone does not affect the stem. For instance Hausa plurals are notated with a suffix which also imposes a tonal melody onto the root as in (19). Following Newman's notation

I will represent a TIA's overwriting tonal melody with the notation ...)^{T} to indicate that tone melody T overwrites that of the entire word.

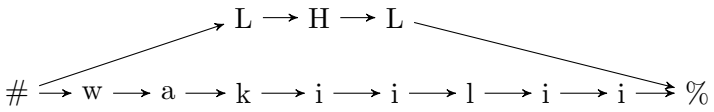
(19)

Bare noun	plural suffix	plural form	gloss
wàkíilìi	ai)^{LH}	wàkìilái	'representative(s)
tsàatsúunìyáa	ooCii)^{H}	tsáatsúuníyóoyíi	'folktale(s)
rìigáa	unaa)^{HL}	ríigúnàa	gown(s)
zóomóo	aayee)^{HLH}	zóomàayée	hare(s)
ráanáa	aikuu)^{LH}	ràanàikúu	day(s)
hànkáakàa	ii)^{LH}	hànkàakíi	crow(s)
jìmḿnáa	uu)^{LH}	jìmǹúu	ostrich(es)
yáatsàa	uu)^{H}	yáatsúu	finger(s)

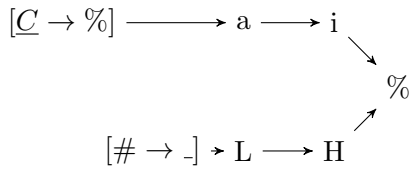
There is a lot going on in (19). I want to focus here on the tone overwrite, however a proper and complete PROP treatment of these forms compliant with chapter 6 would have to handle the massive lexically-conditioned allomorphy in a single underlying form. I will here ignore this aspect, focusing on the tone and taking for granted that once that part is clear it is straightforward but tedious to combine the multiple allomorphs into a single lexical item.

We can posit roots like (20) and an affix like (21).

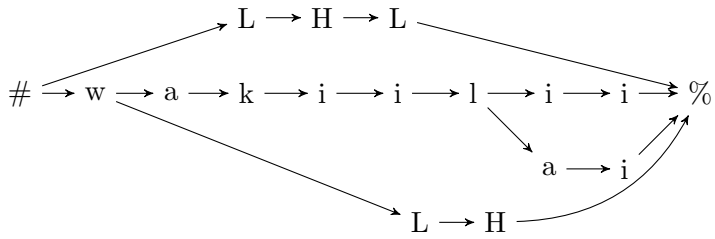
(20) $\sqrt{wàkíilìi}$



(21) plural affix (omitting allomorphy)



(22) *wàkìilái*



The Nesting Principle takes care that the LH melody overwrites the LHL one.

7.4 Sye allomorphy in reduplication

Crowley (1998, p.77-84) and Inkelas and Zoll (2005) discuss an interesting phenomenon of root allomorphy in Sye reduplication. Most roots come in two shapes, a 'basic form' and a 'modified form' (Crowley, 1998, p.77) (Stem1 and Stem2 respectively in the terminology of Inkelas and Zoll (2005)). The amount of modification descriptively varies from root to root, from exceptional invariant roots, to simply adding an 'accretive' n- on so-called weak roots, to vowel replacements and other substantial alterations in so-called strong roots (23-a). Although Crowley identifies multiple generalizations, he admits that the alternation cannot be phonologically predictable as even some homophonous roots have different modified roots

(23-b).

(23) Sye Stem allomorphy

basic root	modified root	gloss
a.		
ahi	ahi	‘just do’ (auxiliary)
aruvo	naruvo	‘sing’
omol	amol	‘fall’
ehri	ahri	‘break’
ve	eve	‘go’
vag	ampag	‘eat’
ocol	agcol	‘dig’
evcah	ampcah	‘defecate’
b.		
owi	nowi	‘plant’
owi	awi	‘leave’
ehkar	nehkar	‘hold feast’
ehkar	ahkar	‘stare’

One of these two forms is selected in any given environment. For instance the basic root is called upon by the distant past affix (24), whereas the modified root is called upon by the future affix (25), where BR and MR stand for ‘basic root’ and ‘modified root’ respectively. The alternation between *co-* and *c-* is not a case of PCA but the regular outcome of vowel-vowel sequences at morpheme boundaries (Crowley, 1998, p.32).

(24) a. y-aruvo
3SG:DISTPAST-BR:sing

b. y-ehri
3SG:DISTPAST-BR:break

c. y-ocol
3SG:DISTPAST-BR:dig

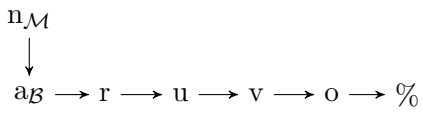
(25) a. co-navuro
3SG:FUT-MR:sing

b. c-ahri
3SG:FUT-MR:break

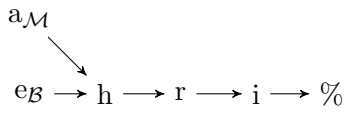
c. c-agcol
3SG:FUT-MR:break

So far this is straightforward to account for in PROP. Roots need to be stored with their two forms and with features identifying the basic and modified forms.

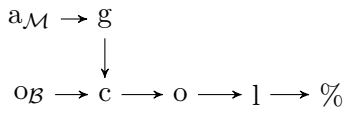
(26) $\sqrt{aruvo}$



(27) $\sqrt{ocol}$

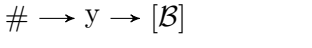


(28) $\sqrt{ocol}$



Affixes in turn need to search for one or the other of the forms of the root. Examples of complete forms are shown for *y-aruvo* and *co-naruvo*.

(29) 3SG:DISTPAST prefix



(30) 3SG:FUT prefix

$$\# \longrightarrow \mathrm{c} \longrightarrow \mathrm{o} \rightarrow [\mathcal{M}]$$

(31) *y-aruvo*

$$\begin{array}{l} \quad\ \mathrm{n}_{\mathcal{M}} \\ \quad\ \downarrow \\ \quad\ \mathrm{a}_{\mathcal{B}} \longrightarrow \mathrm{r} \longrightarrow \mathrm{u} \longrightarrow \mathrm{v} \longrightarrow \mathrm{o} \longrightarrow \% \\ \quad\ \uparrow \\ \# \longrightarrow \mathrm{y} \end{array}$$

(32) *co-navuro*

$$\begin{array}{l} \# \longrightarrow \mathrm{c} \longrightarrow \mathrm{o} \rightarrow \mathrm{n}_{\mathcal{M}} \\ \qquad\qquad\quad\ \downarrow \\ \qquad\qquad\quad\ \mathrm{a}_{\mathcal{B}} \longrightarrow \mathrm{r} \longrightarrow \mathrm{u} \longrightarrow \mathrm{v} \longrightarrow \mathrm{o} \longrightarrow \% \end{array}$$

Sye also has reduplication with the meaning 'all over'. E.g. Crowley (1998) cites *amon* 'hide' > *amonamon* 'hide all over' (p.143). These reduplicated roots are also subject to root modification, but crucially only the first copy is ever modified, e.g. *cw-amol-omol*, 3PL:FUT-MR:fall-BR:fall (p.79).

Inkelas and Zoll (2005) point out the problem that these forms pose for standard theories of reduplication. Derivational theories built on copying segments from a base to a reduplicant that assume allomorph selection is settled at vocabulary insertion cannot explain how the reduplicative process is able to retrieve segments from an allomorph of what it tries to copy. For instance in *cw-amol-omol*, either /amol/ or /omol/ must have been inserted at vocabulary insertion, and the copying process only has that to work with. It cannot go back in time to retrieve the allomorph that didn't get selected.

Constraint-based theories built around base-reduplicant identity constraints suffer from an equivalent problem. Again in *cw-amol-omol*, either /amol/ or /omol/ must be the base, and base-reduplicant identity cannot enforce correspondance between a reduplicant and an allomorph of the base. That would involve going back in time to correspond with the

allomorph that didn't win.

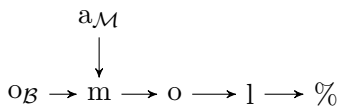
Inkelas and Zoll (2005) suggest a model of reduplication based not on base-reduplicant identity, but on independent spell-out of two roots subject to different cophonologies. Their model radically rethinks reduplication in constraint-based theories. In traditional base-reduplicant OT models, identity between the two copies is the result of base-reduplicant identity constraints, and differences between the two copies are the result of markedness constraints ranked above those base-reduplicant identity constraints. Inkelas and Zoll's Morphological Doubling Theory rather makes identity between copies a function of their common underlying form, and divergence a function of different cophonologies. Crucially if allomorphy is decided by the cophonology then reduplication with different allomorphs is predicted.

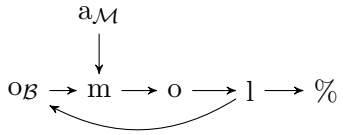
One thing to note is they do not give explicit cophonologies for Sye. If one looks at the table above, it should be clear that there is nothing phonological in common to all the basic roots that distinguish them from the modified roots so the selection process could not be done on the basis of surface optimization as OT is designed to handle. OT seems ill-suited for this task; what is needed is a machinery to select arbitrary forms i arbitrary morphological contexts. The only thing in common among each columns of the table is being a basic root or a modified root, so the cophonology of, say, the 3SG:DISTPAST must directly refer to requiring a basic root. So Inkelas & Zoll are implicitly assuming a phonology that can either recognize arbitrary classes of lexical items or can read their diacritics. This is definitely at most no better than the PROP assumptions I have been making, with lexical items seeking class features stored on roots.

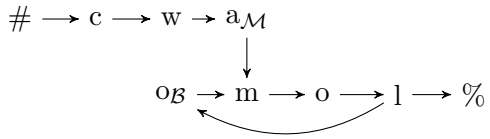
But more interestingly, on top of a no-worse handle on the allomorphy, the PROP analysis of the allomorphy under reduplication has the advantage of requiring no further assumptions whatsoever. The reduplication adds a link from the segment preceding % to the segment carrying [$\mathcal{B}$], which is an unremarkable reduplication. The the prefix adds a

link to the segments of the modified root, and the rest follows from serialization.

(33) derivation of *cw-amol-omol*

a.


b.


c.


This is a neat consequence of PROP. From the point of view of word-formation in PROP (and in the Multiprecedence from which PROP inherits reduplication) reduplication is not a process of copying anything, it is not a process of pronouncing things twice, it is simply a process of adding a path that happens to create a loop, e.g. from the last segment to the first segment. The reduplication pattern can surface with different allomorphs sharing less than all segments in the loop because duplicating segments isn't a goal of reduplication at all, only a side effect of the geometry, hence it does not fall for the problems that Inkelas and Zoll (2005) point to. A path was added from the last segment to the first and the job of word-formation is done. Whether that results in all of these segments being pronounced twice or not is not the problem of word-formation.

With SUF allomorphy, it is simply natural that both allomorphs remain 'available' to be used by other morphemes. If allomorphy is not fully settled at vocabulary insertion then allomorphs can continue to interact with further affixes and phonological processes, just as in this case in which some constructions cause two allomorphs to surface.

7.5 Muskogean reduplication

Many Muskogean languages contain a complex non-local reduplicative pattern in which the initial segments of the root are copied towards the end of the form. Consider these examples from Muskogee in which, descriptively, the initial CV of the root is copied and infixed before the final consonant of the root to form the pluractional of stative roots if said root ends in *k* or *y* or in a cluster.

(34) Muskogee (copied from Riggle 2004)

	gloss	singular	plural
a.	'precious'	a-cá:k-i:	a-ca:**ca**k-í:
b.	'sticking in'	cákh-i:	cak**ca**h-í:
c.	'sticking in & on'	oh-cákh-i:	oh-cak**ca**h-í:
d.	'sweet'	cámp-i:	cam**ca**p-í:
e.	'torn up, mashed'	citákk-i:	citak**ci**k-í:
f.	'frozen, stiff'	cóyh-i:	coy**co**h-í:
g.	'full' (of container)	făck-i:	fac**fa**k-í:
h.	'split' (as of wood)	falápk-i:	falap**fa**k-í:
i.	'crooked'	fayátk-i:	fayat**fa**k-í:
j.	'white'	hátk-i:	hat**ha**k-í:
k.	'clean'	hasátk-i:	hasat**ha**k-í:
l.	'hot'	héyy-i:	hey**ho**y-í:
m.	'ugly, naughty'	holwak-í:	holwa:**ho**k-í:
n.	'broken off'	kálk-i:	kal**ka**k-í:
o.	'old'	lísk-i:	lis**li**k-í:
p.	'nasty, dirty, filthy'	likácw-i:	likac**li**w-í:
q.	'soft'	lowáck-i:	lowac**lo**k-í:
r.	'round'	poló:k-i:	polo:**po**k-í:
s.	'deep'	sófk-i:	sof**so**k-í:
t.	'hard, brittle'	takácw-i:	takac**ta**w-í:
u.	'empty'	tánk-i:	tan**ta**k-í:
v.	'on tiptoe'	tikínk-i:	tikin**ti**k-í:
w.	'hard, firm'	wánh-i:	wan**wa**h-í:

Forms that end in singleton or geminate consonants other than *k* or *y* take the CV copy

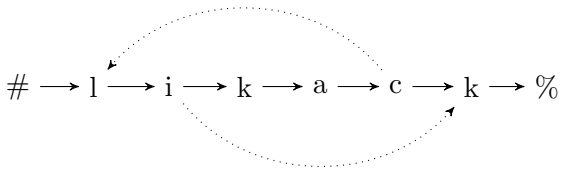
as a suffix + y and simplify the geminate (or do not allow reduplication).

(35) Muskogee (from Martin 2011, p.205)

má:h-i:	ma:h**may**-í:	'tall'
como:tt-itá	como:t**co:y**-itá	'to hop / to be bouncing'
cami:ss-itá	cami:s**ca:y**-itá	'to dodge / to be seesawing'
holá:tt-i:	hola:t**hoy**-í:	'blue'
hónn-i:	hon**hoy**-í:	'heavy'
nika:tt-itá	nika:t**ni:y**-itá	'to nod'

This type of non-local reduplication does have a straightforward account in Raimy's 2000 system. It suffices to add the right arcs in the right places to make the copy of some segments surface anywhere, as in (36).

(36)



But there might be more to say about this pattern. One thing to note is that this pattern of location right before k or y or the last segment of a cluster and suffixed otherwise is exactly paralleled by the infix *-ho-* which is another marker of the dual/plural, mostly for for a different set of verbs: verbs of position or movement[1].

(37) Muskogee *-ho-* (from Martin 2011, p.200)

ay-íta	a**ho**y-itá	'to go'
ta:sk-itá	ta:s**ho**k-íta	'to jump'
hoyan-itá	hoyan**hoy**-íta	'to pass'
at-íta	at**hoy**-íta	'to come'
oss-itá	os**hoy**-íta	'to go out'

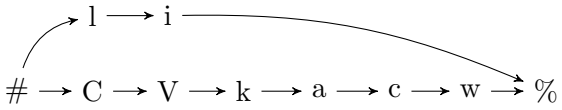
Under an analysis in the style of Raimy (2000), the fact that these two affixes with similar semantics are placed in the same location is an accident. While I do not think this would be a major problem to have a this small amount of repetition in the grammar, I

[1]The constant semantic of *-ho-* is nonsingularity; verbs of position or movement can distinguish singular-dual-triplural, in which case *-ho-* marks the dual. But if a root does not have a triplural form, then the form with *-ho-* also conveys plural.

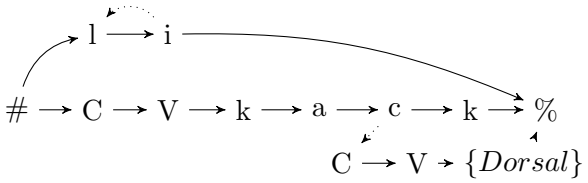
would like to suggest a way the two could be unified using PROP.

I propose that the inititial CV of roots is set in parallel to the rest and realize with an empty CV on the root as in (38). In the normal case this will be pronounced just as if it were linear. The reduplicated form would be as in (39).

(38) $\sqrt{likacw}$



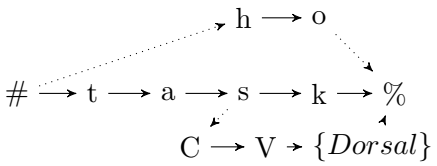
(39) *likac-li-k-*



The idea in (39) is that the plural involves reduplicating the initial CV while also adding an empty CV towards the end of the form. The reduplicated *li* would have to be pronounced where it is compatible, which would put one copy towards the beginning and one copy towards the end. The underspecified $\{Dorsal\}$ feature is simply there to ensure that when there is no final dorsal a default *y* will surface, whereas when there is a final dorsal then $\{Dorsal\}$ will be compatible with it and nothing will need to be added.

Forms with *-ho-* in turn lack the underlying parallel stream but still take the CV$\{Dorsal\}$ parafix as well as a *ho* parafix which will surface on it.

(40) *ta:s-ho-k-*



If the the CV$\{Dorsal\}$ part is its own affix and *-ho-* vs. reduplication (decided via

morphologically-conditioned allomorphy) is another then this unifies the complex placement of these two forms. The CV{*Dorsal*} affix is set to follow non-dorsal segments and precede the end of the word.

7.6 Reduplication with a 'weakened' copy as partial reduplication

Many languages have patterns of reduplication in which one copy is phonologically 'weakened' in a variety of ways. These effects have been largely compiled and studied in Optimality under the rubric of The Emergence of The Unmarked (TETU). The most common manifestations of these are cases where one copy either lacks some structure such as codas as in (41) or contains a fixed segment characterizable in OT terms as 'unmarked' as in (42).

(41) Nootka (from McCarthy and Prince 1994, p. 10)

ʔu- ʔu-'i:ħ	'hunting it'
či- čims-i:ħ	'hunting bear'

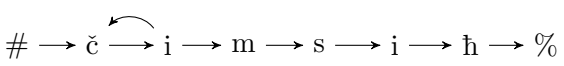
(42) Tübatulabal (from McCarthy and Prince 1994, p. 29)

ʔi-pɨtɨta	'to turn over'
ʔo- tomotska	'to stumbleâ'
ʔa- kamiʧ	'to catch it'
ʔa- maʃa	'to cover it'
ʔe- ʔela	'to jump'

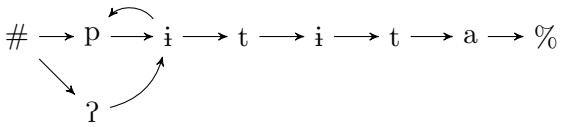
These were straightforwardly handled in Raimy (2000) as either partial reduplication

(43) or fixed segmentism (44).

(43) Nootka[2]



(44) Tübatulabal



However there is another case that would not be so easily accounted for in the model of Raimy (2000): these are cases where one copy's segments 'simplify' compared to the underlying form. Consider continuative reduplication in Nuxalk CC- and CVC- stems in (45).

(45) Nuxalk dorsal neutralization in reduplication (from Newman (1971) unless marked otherwise)

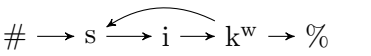
root/stem	cont.	gloss	
nik̓-	nixnik̓	'cut'	§1.2
sk^{w}-	sixsik^{w}	'untie'	§2.11
sx^{w}-	sixsix^{w}	'burn'	§2.11
cak^{w}-	caxcak^{w}	'be long'	§2.12
sik^{w}-	sixsik^{w}	'pull'	§2.12
kix^{w}-	kixkix^{w}	'gnaw'	§2.12
tux-	tuxtux	'unwind'	§2.13
niqâχm	nixniqâχm	'have cramps'	(Carlson, 1997, p.33)
tiiχm	tixtiiχm	'hit'	(Angermeyer, 2003, p.22, citing Nater 1984)

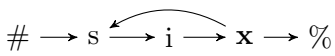
[2]For simplicity here I treat *-čims-i:ħ* as an undivided root, but it is manifestedly a verbal root with an incorporated noun, which would needlessly introduce a lot of complexity in this discussion.

As Newman discusses (fn.6) this pattern of CVx- reduplication only (though not always) occurs when the second consonant is a dorsal, and as such it seems natural to derive this [x] from the underlying dorsal. Some of the explanation may have to do with regular phonology, as several processes delete secondary features in Nuxalk, but it does not seem to be a general fact of Nuxalk that dorsals neutralize in this context, as some dorsals that are not neutralized into [x] can be found in CV_C contexts, e.g. *ʔiƛ̇naax*^{w}*-i* 'crab.DIM' (<*ƛ̇inax*^{w} 'crab') (Bagemihl, 1991, p.598), *ʔix-uk*$^{\dot{w}}$*p ɬx* 'REPETITIVE-stalk' (Bagemihl, 1991, p.604), *ʔak*^{w}*na* '' (Bagemihl, 1991, fn.40). I therefore take for granted that maybe not all but some part of this neutralization is specific to continuative reduplication.

This would be a bit of a challenge for Raimy (2000). The phonological rule neutralizing all dorsals into [x] would have to be ordered either before or after serialization. If it happened before serialization in (46), we would expect both copies to undergo the neutralization, contrary to facts. If it happened after serialization we would have to target only the first k^{w} in (47), but with the PROP assumptions so far we have lost the information that this k^{w} is the outcome of reduplication, and there is no way to target it without making the rule apply to all dorsals in similar contexts, and I have shown it does not.

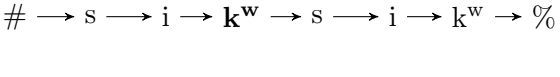
(46)





**sixsix*

(47)

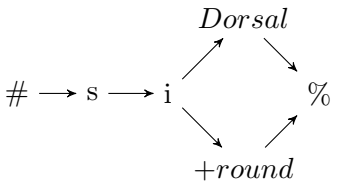


This is an insufficiency of the model of Raimy (2000). While the model is powerful enough to handle some cases of over- and under-application in reduplication, it can only

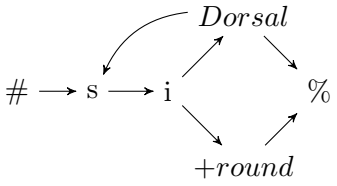
account for cases where the over- and under-application cause both copies to be identical, because the only mechanics for this in Raimy (2000) is for the rule to apply prior to serialization. All rules applying after serialization will display normal application. A process like the Nuxalk one above that is dependent on reduplication without yielding identical copies is not doable with Raimy's (2000) methods.

However PROP can account for the above case if we make some assumptions about the underlying form of these dorsals: if their dorsality is separate and parallel to their secondary features, we can have the reduplicative affix pick only the former without the latter. Adding the assumption that the 'default' dorsal in the language is a velar fricative (an assumption also implicitly present in OT analyses of this data such as Carlson (1997)) we derive the data above.

(48) $\sqrt{sik^w}$



(49) *sixsik*^{w}



$\Longrightarrow$ si{Dorsal}sik^{w}

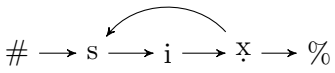
$\Longrightarrow$ si**x**sik^{w}

This analysis is essentially extending the idea of partial reduplication to other kinds of partiality than substrings, namely by picking a portion that does not contain all underlyingly parallel features.

With this analysis it is also very straightforward to account for the stems that do not undergo this neutralization. They are simply stored without the split posited above. E.g.

sx̣- >six̣sx̣- (Newman, 1971, §2.12). In this respect there are no 'exceptions' in PROP, there are only different inputs.

(50)



Patterns of reduplication-specific neutralization are relatively common. Many are mentioned in Rose (1999) and they would all receive a similar PROP analysis to the Nuxalk one above.

In (49), the realization of the reduplication is taken to be through only the Dorsal part in the first copy, and through both the Dorsal and *+round* parts in the second, but another logical possibility would be to only go through the *+round* part in the second copy, seeing as the Dorsal part is already traversed.

I would like to posit that both of these realizations are possible, based on language-specific parametrizaion, as the opposite scenario can also be observed. Struijke (2002), in the context of OT, discusses a few patterns of reduplication in which both copies differ from the unreduplicated form. This is descriptively the scenario in which some part of the input has some features surfacing only in the first copy and other features surfacing only in the second copy.

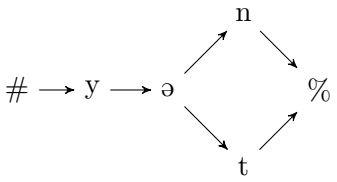
(51) Tohono O'odham

yənt	yən-yat-m'u:t	'gnawings of a large animal'
qəns	qən-qas-m'u:t	'chips'

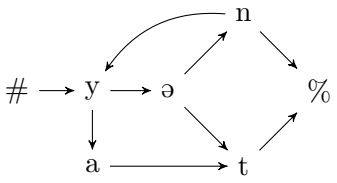
In PROP this can simply be seen as an underlying form like (52) reduplicating as in (53). The pronunciation of (52) with [nt], given that [n] and [t] cannot be simultaneous, is a simple assumption that we can derive either as a phonological rule adding an arrow from *n* to *t* in this context, or from a principle, either language-specific or generic to motor

planning, that [nt] is a 'better' realization of unordered n and t than [tn].

(52) *yənt-*



(53) *yən-yat-*



So as we can see, one property of PROP is that it allows for elements to be independent enough that they are separable by some affixes such as the reduplicative affixes above.

It is important to acknowledge at this point that I am deriving contradictory effects from the same representation. The same topology is posited to result in one weakened copy in Nuxalk but in two weakened copies in Tohono O'odham, with the pronunciation somehow choosing differently whether to re-traverse the upper node that was traversed in the first copy. This is a problem with the vagueness, indeterminacy, and speculativeness of my linking hypothesis with regard to the pronunciation of graphs. It might not be plausible that the motor-planning of these graphs be parametrizable on a language-specific basis. Further research will have to take place and it is very possible, in fact very likely, that not all the analyses I have proposed are simultaneously tenable.

Chapter 8

Using and learning graphs

In this chapter we will discuss all issues of implementation, acquisition, and neuroscience that I have found to be relevant to the PROP program.

8.1 Phonetic implementation

Many assumptions about Phonetic implementation have been made in this thesis. I will spell out the assumptions the PROP analyses require so far and attempt to justify them.

An assumption made by researchers who have worked with Multiprecedence representations involving loops has been that the representation, however non-linear it gets in the course of word-formation, must be linear to be sent to the phonetics which can only deal with strings (e.g. Samuels and Boeckx 2009 for an explicit statement to the effect.) The core reasoning seems to be that while mental representations can be a-temporal abstract structures, physical realizations must occur one at a time and that requires a string to pronounce.

But multiple gestures can be done at the same time. A pianist can move their hands in parallel with very different movements and therefore using very different articulatory commands. It would seem difficult to me to account for the behavior of pianists linerarly without attributing to them the capacity to have separate articulators receiving separate commands in parallel. There must be a level of representation in which the input to articulators is not flat, and it is not therefore logically necessary that the output of phonology be flat either. A weaker assumption would be to allow representations with either serial or parallel commands to be interpretable, i.e. anything without loops. The acyclic graphs of ch.7 are what we want.

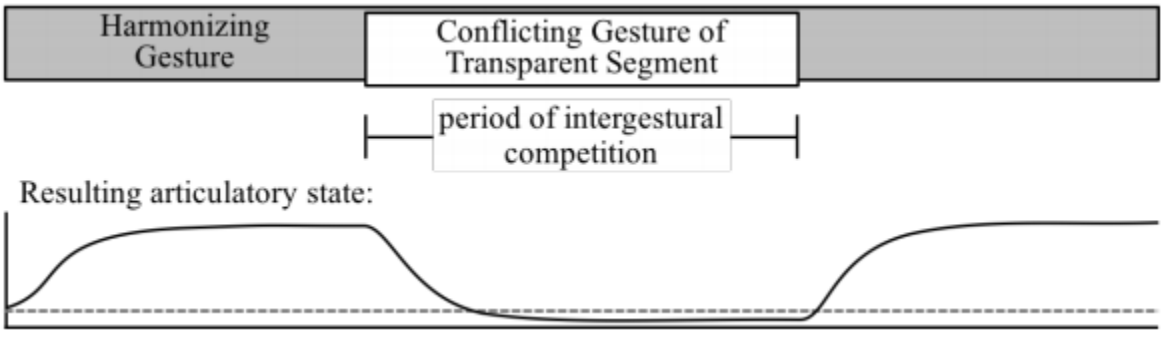
One issue that must be addressed in more details is the phonetic behavior of representations with contradictory parallel features. A central principle of this thesis is that

contradictory features can be set in parallel in the representation sent to phonetics, with the assumption that they will be resolved by the Nesting Principle. In this section I will examine the existing precedents and circumstancial evidence in favor of it, but I cannot conclusively argue that it is independently justified.

First, the assumption of simultaneous contradictory features was proposed first by Smith (2018b) couched in Articulatory Phonology in which she posits complete gesture overlap between features to account for vowel harmony with transparent vowels. Smith represents vowel harmony in terms of a single feature spanning the whole word, with transparent segments specified with a contradictory feature and winning. Her diagram in (1) is something that could very well have figured in ch.3.

> I propose that in the Gestural Harmony Model, transparent segments are not neutral to harmony, but instead that they are overlapped by a harmonizing gesture. Transparent segments, then, are just a special type of undergoer. In this model, transparency to harmony is the result of the concurrent activation of a harmonizing gesture and a gesture that is antagonistic to it. Two gestures are antagonistic if they have directly opposing target articulatory states that strive to pull an active articulator in opposite directions. (Smith, 2018b, p.195)

(1) Schematic representation of transparency in the Gestural Harmony Model (Smith, 2018b, p.197)



The similarity ends there however, as Smith does not propose a general principle resolving those conflicts, but rather a feature-by-feature gestural strength deciding the winner of

the conflict in case of incompatible overlaps, and capable of gradient blending. It would be possible to modify the PROP account of this thesis to replace the Nesting Principle with Smith-type strength specification, but I will not explore the possiblity here.

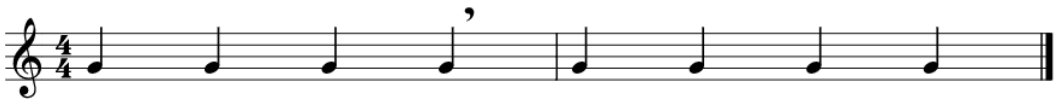
8.1.1 Nesting Principle

We made the major assumption in chapter 3 that if two features are parallel but one of them is so-to-speak 'nested' into the other, the inner one wins. This was crucial to deriving vowel harmony facts in Turkish and Finnish.

Proving this fact however is beyond my abilities. All I hope to do in this section is provide two analogs that make it plausible to me that the nesting principle might be a deep fact about the organization of motor commands, namely that a motor plan can include contradictory specifications, and that when one is nested within another a gesture or state can be interrupted and resume afterward.

Consider first an example from music. Sheet music for wind instruments often contains breath marks over the staff indicating when to breathe, as in (2). Breathing is not meant to interrupt the rhythm, and as such it must happen during the duration one of of the notes. By convention the note immediately prior to the mark is played slightly shorter to allow for the breathing.

(2)



With the intuitive assumption that the sheet music is representative of the musician's mental representation of the song, as opposed to the musician actually representing the sixth measure of above as containing a shorter fourth note and a silence, then there is a level of representation in which they represent both the notes and the breathing. Zooming in on the sixth and seventh measure for instance, the musician would represent eight quarter notes and one breathing period during the fourth of those. The muscle commands to the diaphragm would require something like (3). And crucially where blowing out conflicts with

breathing in, the command embedded in the other one wins.

(3)
```
Blows:    <===><===><===><===><===><===><===><===>
Breaths:                      <>
```

We therefore have an example that seems at least analogous to the nesting principle in phonology: a mental representation containing contradictory commands in which the nested command wins[1].

For a second example, it is worth noting that what I am suggesting is the production analog of a well understood process in perception. In vision for instance the perceptual systems typically infers continuity in the case of occlusion as in (4).

(4) Visual occlusion

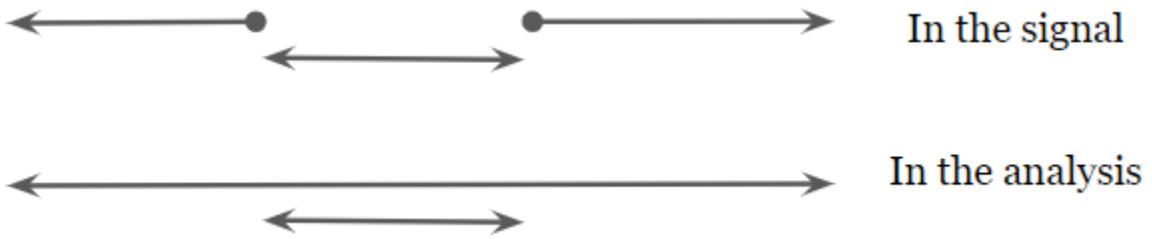
Analogous auditory versions of this exist too, with perceived continuity where a sound appears 'hidden' behind another. See O'Callaghan (2008) for a recent overview.

Crucially, the nesting principle proposal is the inverse of occlusion completion in perception. Abstractly perception is able to perform as in (5) with a discontinuity in the signal interpreted as continuous in the percept. The claim here is that production is able to do as

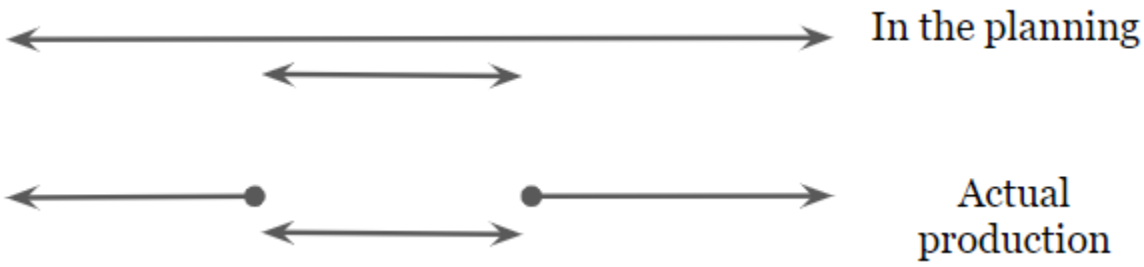
[1]It is not logically necessary that the Nesting Principle is the operative principle here. This is simply illustrative of the possibility of resolving contradictory commands of a representation by performing a single one of the two.

in (6), with a continuity in the motor commands realized with a discontinuous output.

(5) Abstract illustration of occlusion completion in percetion



(6) Abstract illustration of interrupted parallel commands in production



Other aspects of Auditory Scene Analysis are relevant to PROP and we will come back to them in section 8.2.

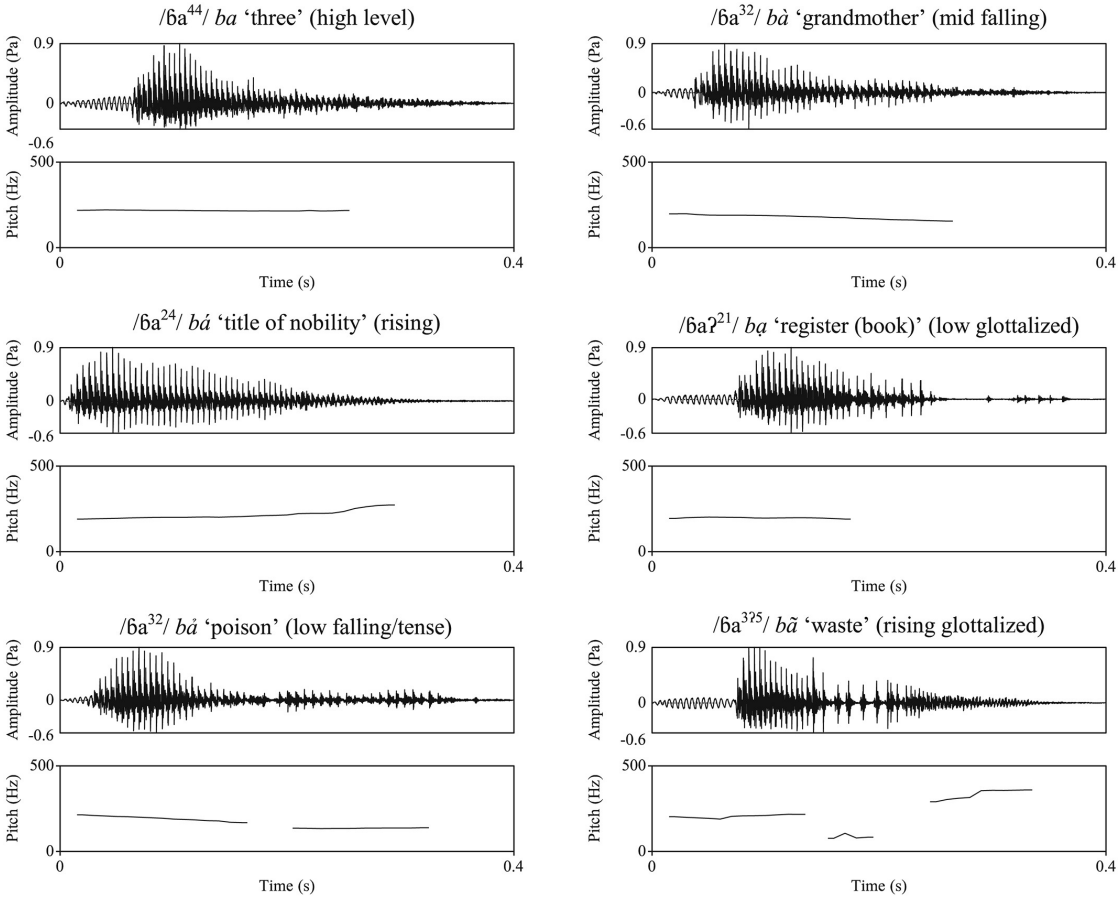
8.1.2 Resuming gestures

An assumption of the model of harmony with parallel contradictory features is that there is such a thing as *resuming* a gesture, as distinct from starting a new instance of the same gesture, maybe not at the phonetic level, but at least in the planning.

There are also other domains of Phonetics where features are best analyzed as interrupted and resumed. Consider the glottalized tones of Vietnamese for instance as in the lower right diagram in (7). Glottalization, variably realized as a glottal stop or as creakiness, interrupts a vowel's voicing, which then resumes. It would seem inadequate to analyze this phonetic [V?V] sequence as such; it is rather universally treated as a single vowel, in-

terrupted by glotalization, which then resumes with modal voice.

(7) Tone and phonation in Vietnamese (Brunelle and Kirby, 2016)



This type of vowel glottalization exists beyond South East Asia, e.g. the [+glottal closure] vowels of !Xóõ (Bradfield, 2014, p.11), or the so-called rearticulated vowels of multiple Mayan languages (Bennett, 2016).

Another relevant phonetic finding is that of Heid and Hawkins (2000) and Kochetov and Neufeld (2013) with regard to long-distance coarticulation. They found that coarticulation caused by [r] vs. [l] vs. [h] is detectable even 4 syllables away, e.g. on the word 'heard' [hɜd] in *We heard it might be (a) ram/lamb/ham.* Interestingly they found that sometimes the closer word *might* is not influenced because of stress. This is long-distance [r] and [l] coarticulation that crosses a word that is itself resistant to it. This has all the hallmark of an [r] or [l] gesture starting early and being interrupted by a stressed word before resuming.

8.2 Acquiring the parallel features of vowel harmony

In section 8.1 I have suggested that the Nesting principle may be the production analog of the gap-filling principle in perception. Just as in vision an interrupted object whose ends are sufficiently aligned is perceived as continuous, in audition an interrupted auditory object is also perceived as continuous if it is interrupted. This fact of perception may have important implications for the acquisition of vowel harmony. In general it has been taken for granted that segments are perceived in isolation and any correlation between them due to phonology must be observed and then explained by a phonological process. Thus for instance vowel harmony would be harder to learn than the lack thereof, as learning it implies noticing the correlation between the segments of a word along one or more feature and abducing a rule from it. But this may not be true: if a discontinuous feature is perceived as continuous by the low-level perceptual system, it may be that we have had it backward all along: it is vowel harmony that is easy to learn, since the continuity of the harmonizing features is directly perceived. Rather it might be the reverse, concluding from similar segments which could be the product of a single continuous feature that they must be different entities, that is hard.

To give a concrete example, consider a Finnish front word like *tyhmä-stä*, 'stupid-ILL.'. A traditional account would have the form parsed by the learner first as as a string of segments as in (8). Then, on this representation, after being exposed to enough words, the learner may notice the correlation between all Back features of Finnish words and posit a rule of vowel harmony.

(8) Segmental parse of *tyhmä-stä*

$$\left\{\begin{matrix}+cor\\-voi\\...\end{matrix}\right\}\left\{\begin{matrix}-bk\\+hi\\...\end{matrix}\right\}\left\{\begin{matrix}-voi\\...\end{matrix}\right\}\left\{\begin{matrix}+lab\\+nas\\...\end{matrix}\right\}\left\{\begin{matrix}-bk\\+lo\\...\end{matrix}\right\}\left\{\begin{matrix}+cor\\-voi\\...\end{matrix}\right\}\left\{\begin{matrix}+cor\\-voi\\...\end{matrix}\right\}\left\{\begin{matrix}-bk\\+lo\\...\end{matrix}\right\}$$

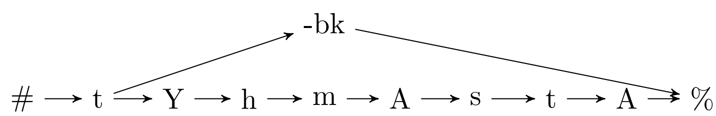
But if gap-filling in auditory scene analysis plays a big role, it may be that *tyhmä-stä* gets immediately parsed as containing a continuous -back feature, going at least from the

first vowel to the last, as an automatic perceptual fact, the representation may be more like (9), or simply (10). Under this account, harmony does not require much analysis on the part of the child; it is instead almost a given of auditory cognition. The learner would still have to figure out that *-stä* is a suffix, but that is true in any model.

(9)

```
-Back:            <--------------------------------------->
+High:            <----->
+Low:                                <----->       <----->
+C:        <----->       <---------->       <----->
```

(10)

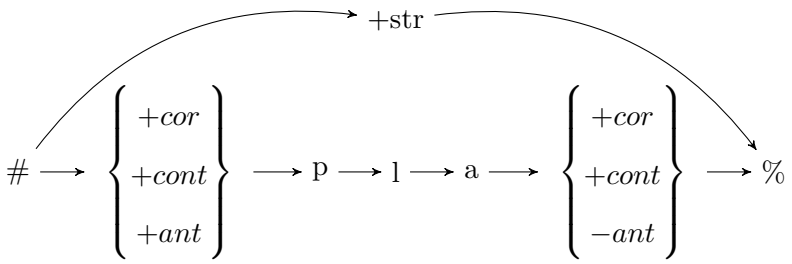


The idea that children might learn by features rather than starting from segments and that they have very non-surface-like assumptions about the organization of those feature are two very unorthodox hypotheses, but I do not think that there is any a priori reason to reject them. Why should the child segment speech into a flat representation if phonology is freer than this? Why should initial analyses of speech be very surface-like if we know that general audition itself is not completely faithful to the signal?

This of course opens up many more questions about children's and adult's representations of all features that could be perceived as continuous but obstructed. Consider a word like *splash* with, on the surface, a strident at the beginning and one at the end. Could this

form be parsed as (11) with a continuous strident feature throughout the form?

(11)

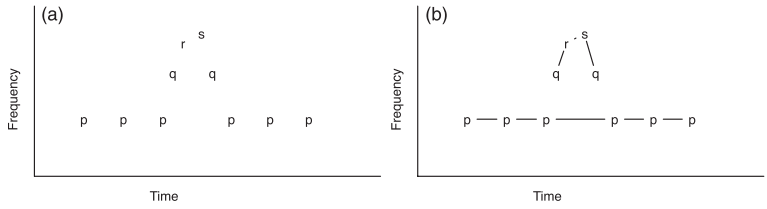


This may seem strange at first, but a parse such as (11), at least at some initial stage of acquisition may capture diacronic metathesis that Blevins and Garrett (2004, p.127-128) attribute to the decoupling of sibilant noise from the rest of the speech stream. They cite Ilokano *saait* 'weep' vs Aklanon *taais* as a pair of cognates that may originate in this way from a long distance metathesis. Under the view presented here this sound change may boil down to a speaker starting from a parallel analysis in the lines of (11) and resolving it in a different way from the speakers of this learner's input.

There is additional data from the field of Auditory Scene Analysis in favor of auditory segmentation into multiple streams. Warren et al. (1969) played their subjects a repeated sequence of a high tone, broadband noise, and a low tone, or a high tone, a hiss, a tlow tone, and a buzz, each 200ms long, which as they observe is much longer than typical phone length. Even though the subjects were fully able to identify the three or four sounds involved, they had trouble telling the order in which they played. They conclude that perception of linear order is more difficult than intuitively expected.

The interpretation of this experiment by Bregman (1994) is that some sounds are too different to be parsed as a single stream and are parsed into different parallel streams that are not ordered in time. Similarly souns in the same category but with abrubt transitions also tend to be parsed as separate streams as O'Callaghan (2008) discusses for tones.

(12)



In light of such results the idea that some features like tone, nasality or specific formants perceptually clash against others in a way that incites or even forces the child to initially parse them as separate streams is a very plausible hypothesis. Again, language-independent perceptual facts support that the initial parse may not be a segmental parse in the style of (8). This is a somewhat different take-away from Auditory Scene analysis than the one of Reiss (2007, p.67) who posits that the contribution of auditory perception to linguistics is that speech gets parsed into its own stream, thus giving the learner a single string to learn from decoupled from non-linguistic noise. Here I posit that even the input to speech perception may consist of multiple streams.

If this is correct, contrary to segment-oriented bottom-up intuition, vowel harmony is not hard to learn; it is basically not learned. Rather non-harmonic languages with misleadingly harmonic words like Spanish *banana* are the actual challenge, as the learner must realize that all these [a]'s are multiple objects, not a single partially obstructed one. This is like being forced to learn that there are actually two pale grey objects in (4).

This tendency for the learner to assume continuity by default would also explain the very common fact of OCP at the tone level: languages that are best analyzed as having separate tone melodies from the segments overwhelmingly (but not universally, see Odden 1986) do not allow for multiple consecutive instances of the same underlying tone, *HH, *LL, regardless of what they allow on the surface. If the acquisition of these patterns involves parsing the tones into their own perceptual stream, then multiple consecutive surface H tones will seem continuous by default, which could very well drive the cross-linguistic rarity. The typological fact would therefore boil down to a non-linguistic fact of how general audition necessarily deals with tones that are to be interpreted as parallel to the segmental tier, and the OCP for tone thus does not need to be its own phonological principle.

The idea of taking advantage of the inherent perceptual independence of some phonetic features is a departure from the existing segment-oriented algorithms that have been offered for the learning of harmony patterns and non-concatenative morphology. For example the research program formalizing vowel harmony in terms of tier-based strictly local constraints (Heinz et al., 2011; Aksënova et al., 2016; Aksënova, 2017; Aksënova and Deshmukh, 2018; McMullin et al., 2019) starts from strings and then constructs tiers onto which the generalizations of vowel harmony and other long-distance restriction are to be stated. Similarly Fullwood (2018) seeks to model the segmentation of Semitic non-concatenative morphology in terms of a Bayesian learner testing the most parsimonious segmentation of a string of segment into possibly discontinuous morphemes. Both of these models have in common that they take a segmented string as an input and parse them into subsequences that are themselves strings of segments. I propose that these assumptions are wrong: the input to the child's learning process is not a string, but a set of relatively independent streams, and the ouput is not tiers of full segments, but tiers of sparse features. Fullwood improves on her model by adding certain biases such as a bias for discontinuous morphemes that are fully consonantal or fully vocalic, but this too may be in the percept. This bias does not need to be a learning bias if it is a perceptual bias.

8.3 Planning parallel articulations

Ever since Lashley (1951), speech has been considered part of what he called the problem of serial order in behavior. Models of speech production have mostly focused on accounting for the fast serial organization of speech, developing rich models of speech production that can account for real-time segment-to-segment speech production. For example Guenther (2016, ch.7) discusses how feedforward neural nets can achieve rapid transitions between segments, treating the problem of very fast transitions in speech as the main issue. Nothing is said on the problem of coordination or simultaneity.

PROP changes the problem of speech as it does not require all speech to consist of quickly serially-ordered segments. Some instructions may be organized in parallel and overlap in time. This does not make speech *not* a problem of serial behavior, but it does suggest

that it may be less serial than commonly thought. Contrary to segments changing every few milliseconds in a single stream, we can imagine multiple streams with relatively slower changes overall. This view is not fully novel, as it is shared with Articulatory Phonology's conception of a gestural score.

Of course some utterances will actually require rapid alternations, but in the extreme these utterances will be tongue twisters, and those do get harder to articulate.

The one aspect of simultaneous motor planning that has been somewhat studied in neuroscience is prosody, but the research must be treated with caution as the research tends to treat linguistic prosody as closer to affective prosody than to non-prosodic linguistic articulation, and sometimes seems to lump all prosody together. Within linguistic prosody it tends to treat intonation, suprasegmental features, and laryngeal features as essentially co-extensive phenomena. And within linguistic intonation studies are mostly restricted to focus intonation (e.g. Mayer et al. 2002), which is different in so many ways from the more phonological intonation that it would be surprising if its processing was not different[2].

8.4 Alignment as a coordination problem

One aspect that PROP does not seek to explain when contrasted with Autosegmental Phonology is the overwhelming commonality of one-to-one alignment in the realization of parallel phonological structures. Autosegmental phonology attempts to explain it within the phonology through an association convention.

I would like to suggest that this does not need to be explained phonology-internally. There are limitations on the temporal coupling of movements. Heuer (1996) mentions the difficulty of simultaneously tracing a circle and a triangle in the air, other than by forcing a temporal alignment such as one revolution of the circle for every side of the triangle. The details of the difficulty of maintaining different rhythms of movement has been studies for instance by Klapp (1979, 1981); Klapp et al. (1985). Keele et al. (1985) further argued that perception and motor production share a common timing mechanism, and thus the

[2]Focus intonation is not clearly based in rules anywhere similar to those of phonological intonation. A major strangeness about focus is its universal or nearly universal phonetic realization, making it very unlike other syntactic features. Its conditioning also taps into information, discourse, conversation, and communicative pressures in ways that do not resemble phonology.

limitation on timing would affect both perception and production.

Chapter 9

Further Phenomena, Analyses, Observations, and Suggestions

In this chapter we will briefly cover a number of theoretical and analytical questions that either deserve some attention or for which PROP provides a novel insight, but which will not be discussed in depth and deserve to be the subject of further research.

9.1 Regular Phonological Processes

The PROP model discussed so far does not replace regular phonology, and thus we still seem to need something to acheive the effect of normal segment-changing phonology but on graphs. This is a matter that was already discussed in Raimy (2000) so we will start with a discussion of his proposal.

9.1.1 Phonological Processes on Graphs in Raimy (2000)

Raimy (2000) discussed the matter of phonological rules applying on multiprecedence graphs to discuss the descriptive advantage that this offers to explain various phenomena of over- and underapplication in reduplication and infixation. I will only summarize two of Raimy's examples here from Akan and Sundanese.

Consider the case of the interaction between reduplication and palatalization in Akan discussed in Raimy (2000, p.18-23). Dorsal phonemes are palatalized before non-low front vowels i/ɪor e/ɛ.

(1)

tɕɛ	*kɛ	'divide'
dʑe	*ge	'receive'
ɥi	*wi	'nibble'
çɪ	*hi	'border'
ɲɥɪn	*ŋwɪn	'weave'

The only exception to the generalization that dorsal segments do not appear before non-low front vowels is in some reduplicated forms in Cɪ- in which the consonant is not palatalized.

(2)

kɪ-kaʔ	*tɕɪ-kaʔ	*tɕɪ-tɕaʔ	'bite'
hɪ-hawʔ	*cɪ-hawʔ	*çɪ-çawʔ	'trouble'

However this ban on palatalization is not a property of the construction itself, since when the first consonant of the 'base' is a non-low front vowel the palatalization does take place.

(3)

dʑɪ-dʑe	*gɪ-ge	'receive'
tɕɥi-tɕɥeʔ	*kwi-kwe	'cut'

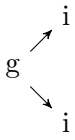
Raimy's (2000) analysis, which I will adopt here, is only statable on a multiprecedence representation of the reduplicated form. Raimy's insight is to point out that on a graph, there are multiple ways that classical phonological rules could be stated. E.g. consider a rule that palatalizes /g/ when it precedes /i/. It seems intuitive that the rule should apply to a form like (4). But what about (5) with /g/ followed by one /i/ and one /a/ vs. (6) in which /g/ is followed by two /i/'s?

(4)

g ⟶ i

(5)

(6)

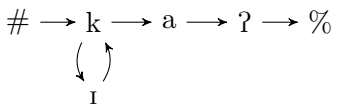


Raimy's suggestion is to posit a Uniformity Parameter on rules. Rules can be parametrized to apply either a) when all segments match the environment (so for our palatalization rule, only (4) and (6) would undergo palatalization), or b) when at least one segment matches the environment (so for the same palatalization rule, all three of representations above, (4), (5), and (6), would undergo palatalization).

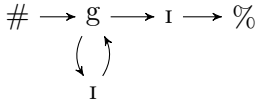
So returning to Akan, given that the forms of [kɪ-kaʔ] and [d͡ʑɪ-d͡ʑe] would look like (7), the crucial difference is that in (7-b) the /g/ precedes only non-low front vowels, whereas in (7-a) the /k/ precedes a mix of non-low front vowels and other vowels. Hence if the Akan palatalization rule is set with its Uniformity Parameter on, it will apply in (7-b) and not (7-a), and it will apply in non-branching forms like (1), deriving all the facts.

(7)

a.



b.



An example of the Uniformity Parameter set to off is found in the interaction between

infixation and nasalization in Sundanese discussed in Raimy (2000, p.71-74). Sundanese has a nasalization process in which nasal vowels cause nasalization of vowels to their right, with /h/ and /ʔ/ transparent to the process, but blocked by supralaryngeal non-nasal consonants.

(8)

mãro	'to halve'
mãnẽh	'you'
mãndi	'to bath'
mĩ̃ãsih	'to love'
kumãhã	'how?'
ɲãhõken	'to inform'
beŋhãr	'to be rich'

However an exception to the generalization that oral consonants block nasalization is the infix *-ar-* (or *-al-* when an /r/ follows), which lets nasalization through (aside of a local de-nasalization of vowels immediately following an oral vowel). In (9) the nasalized vowels after the infix go against the generalization that /r/ blocks the spread of nasalization.

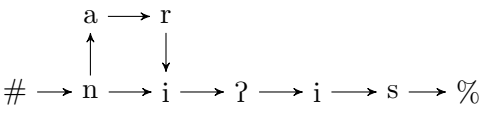
(9)

mõẽken	m-ãr-oẽkən	'to dry'
ɲãũr	ɲ-ãl-aũr	'to say'
nĩ̃ʔĩ̃s	n-ãr-iʔĩ̃s	'to cool oneself'
ɲãhõ	ɲ-ãr-ahõ	'to know'

Raimy's answer is to look at the multiprecedence form of infixation. E.g. the form [n-ãr-iʔĩ̃s] would have the form in (10) prior to the application of the phonological rule. Even though on the surface the /r/ intervenes between /n/ and the two /i/'s, at this point in the derivation there is a path from /n/ to the vowels that bypasses the infix. If the nasalization process applies on this representation, and crucially if the Uniformity Parameter is off, meaning nasalization will happen as long as there is at least one preceding nasal segment, then the first /i/ will nasalize and spread nasalization to the right (and will subsequently

de-nasalize due to the /r/). This derives the overapplication effect.

(10)



I will maintain this analysis, but I will avoid the language of Uniformity Parameter and convert the proposal into the notion of properties I introduced in ch.2 using the symbols $\stackrel{\exists}{\rightarrow}$ and $\stackrel{\forall}{\rightarrow}$, giving rise to properties defined as in (11) and (12), which respectively read as 'has at least one preceding segment containing +F and +G' and 'has only following segments containing +F and +G'. Crucially, $\stackrel{\exists}{\rightarrow}$ and $\stackrel{\forall}{\rightarrow}$ are not novel phonological relations, they are a notation summarizing a first order property over graph relations.

(11) $[[+F, +G]\stackrel{\exists}{\rightarrow} \_] \equiv \exists u_{u \rightarrow \_}(\{+F, +G\} \subset u)$

(12) $[\_\stackrel{\forall}{\rightarrow} [+\text{F}, +\text{G}]] \equiv \forall u_{\_ \rightarrow u}(\{+F, +G\} \subset u)$

These properties can be used in rules as in (13) and (14)[1], in which the context stands for properties that A must have in order for the rule to apply. A rule may contain multiple such properties as in (15).

(13) $A > \text{B}/[[+F, +G]\stackrel{\exists}{\rightarrow} \_]$

(14) $A > B/[\_\stackrel{\forall}{\rightarrow} [+\text{F}, +\text{G}]]$

(15) $A > B/[[+F, +G]\stackrel{\exists}{\rightarrow} \_]$ & $[\_ \stackrel{\forall}{\rightarrow} [+\text{F}, +\text{G}]]$

Note that this same notation can be used in sticky-ends. The $\stackrel{\exists}{\rightarrow}$ / $\stackrel{\forall}{\rightarrow}$ system allows us to define different types of sticky-ends: $[\_ \stackrel{\exists}{\rightarrow} [+F]]$ which seeks any segment that precedes some $[+F]$ segment, vs. $[\_ \stackrel{\forall}{\rightarrow} [+F]]$ which seeks segments *only* followed by $[+F]$ segments. We will see this difference in use in the next section.

[1] I will avoid the use of arrows to represent change in phonological rules since the arrow is already used for precedence.

9.1.2 Phonological processes on Graphs in PROP

With a way to do phonology, we can discuss a number of phonological phenomena whose analyses become better understood thanks to the graph representation of the form.

9.1.2.1 Overapplication in Brazilian Portuguese

As discussed by Ferreira (2005), Bachrach and Nevins (2008) and Rolle (2018), Brazilian Portuguese has a process of *l*-vocalization by which /l/ becomes [i] before /s/. This process affects l-final forms in the plural as in (16-a). The diminutive singular form with -*zinho* in (16-b) is not affected, showing that /z/ does not trigger the phonological change. But the diminutive plural *jornaizhinos* does undergo l-vocalization, despite the distance.

(16)

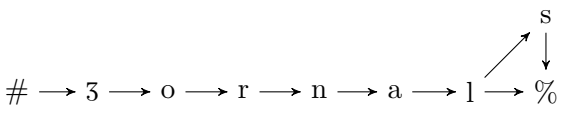
	sg.	pl.	
a.	jornal	jorna**i**s	'newspaper'
b.	jornalzinho	jorna**i**zinhos	'newspaper.DIM'

This can be straightforwardly given an explanation in PROP. The plural is set to follow any segment that precedes the end of the word, as in the UR in (17). When added to the bare root it will create the form in (18) which naturally satisfies the condition of l-vocalization.

(17) Brazilian Portuguese plural suffix

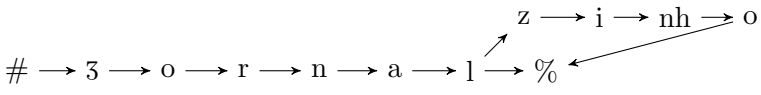
$$[\_ \overset{\exists}{\rightarrow} \%] \longrightarrow \text{s} \rightarrow \%$$

(18) $\sqrt{jornal}$+-*s*

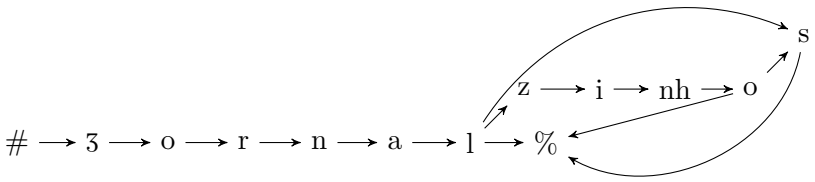


However when appended to the form with the diminutive as in (19)[2], the plural will find two segments that precede the end of the word, and thus will attach as in (20), in which /l/ does precede /s/.

(19) $\sqrt{jornal}$+*-zinho*



(20) $\sqrt{jornal}$+*-zinho*+*-s*



Assuming that *l*-vocalization is defined as in (21), the rule will indeed find that the /l/ of (20) has the property of having at least one following segment that is /s/, and therefore the rule will apply.

(21) $l > s \;/\; [\_\overset{\exists}{\rightarrow} s]$

We therefore derive this form of overapplication across a morpheme from the allowed combinations of the Uniformity Parameter in sticky-ends and rules. The Brazilian Portuguese case can only happen because both the sticky-end and the rule are defined existentially.

This analysis dispenses with the invocation of Paradigmatic or Trans-paradigmatic Output-Output constraints that have been proposed to account for this kind of fact (e.g. Ferreira (2005), Rolle (2018)). It is replaced with the representational possibility that seg-

[2]I oversimplify a bit as *-zinho* is presumably two morphemes, a diminutive *-zinh* and a masculine morpheme *-o*, but it does not affect the analysis.

ments may covertly be related by a precedence link even though they surface apart from each others, and that this link can make them local for the purpose of phonological rules.

Brazilian Portuguese has other suffixes across which *l*-vocalization does not take place, most notably the augmentative *-zão*. *jornalzão* becomes *jornalzões* in the plural and not **jornaizões*. As noted by Bachrach and Nevins (2008) however, the augmentative has different properties, such as changing the gender of roots, and thus may have different structure, e.g. as the head of a compound. Importantly the account of *l*-vocalization in this section does not entail that it should occur across all suffixes; what it entails is that suffixes that block *l*-vocalization must have a different structure than (20) at the point in the derivation where *l*-vocalization happens. Possibilities include not being a suffix at all, like in the compound analysis of *-zão*, or having triggered serialization to happen before *l*-vocalization.

Rolle (2018) describes other cases of phonological processes taking place across affixes, such as CiBemba spirantization taking place across the benefactive derivational suffix. This is therefore not idiosyncratic to Brazilian Portuguese, it is simply a representational possibility available to phonological systems.

9.1.2.2 Quebec French laxing harmony

Some varieties of Quebec French have a process of vowel harmony as described in Poliquin (2006). I will focus here on what Poliquin calls Across-the-board (ATB). There are three phonological processes that interact in Quebec French: High-vowel laxing, laxing harmony, and pre-voiced-fricative tensing.

With high vowel laxing, high vowels becomes lax in final closed syllables. This is visible

in the vocabulary in general (22-a) as well as in morpheme alternations (22-b).

(22) High-vowel laxing

a.

li	'bed'	e.lɪt	'elite'
kʁy	'raw'	aʁ.bʏst	'bush'
de.gu	'disgust'	e.gʊt	'drain'

b.

be.ni	'blessed.masc'	be.nɪt	'blessed.fem'
pœ.tsi	'small.masc'	pœ.tsɪt	'small.fem'
de.by	'start' (noun)	de.bʏt	'start.imperative'
a.ʒu	'add-on' (noun)	a.ʒʊt	'add.imperative'

In some varieties, this laxing gives rise to a laxing harmony. High vowels in previous syllables become lax, even in open syllables.

(23) Laxness harmony[3]

No harmony	ATB	gloss
ʒy.ʁi.dzɪk	ʒʏ.ʁɪ.dzɪk	'judicial'
si.ʁi.lɪk	sɪ.ʁɪ.lɪk	'cyrillic'
ny.tʁi.tsɪf	nʏ.tʁɪ.tsɪf	'nutritional'
dzi.si.plɪn	dzɪ.sɪ.plɪn	'discipline'
li.mu.zɪn	lɪ.mʊ.zɪn	'limousine'

A traditional analysis of this phenomenon would involve a two step process: first insertion of a lax feature[4] in the final vowel, followed by spreading or copying of the feature to previous segments. In PROP on the other hand laxing and laxing harmony can be made

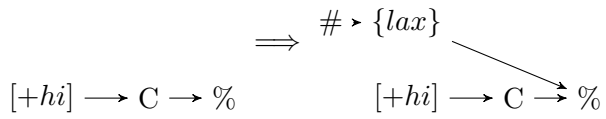
[3] I am skipping Poliquin's category of Non-local harmony as it is not relevant to our purposes here and there are reasons to believe it is misanalysed, see e.g. Cuerrier and Reiss

[4] I will not discuss here the exact details of the phonetics of the QF tense-lax contrast, as it is poorly understood. Dalton (2011) suggests that it has nothing to do with advance or retraction of the tongue root. I will therefore use 'tense' and 'lax' features with the hope that further phonetic study could inform us of the appropriate features to use.

into one single process that adds a lax feature in parallel to the entire word.

(24) QF Laxing rule[5]

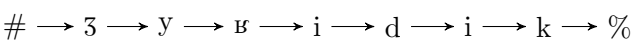
When a +hi segment precedes a final vowel, add Lax from # to %.



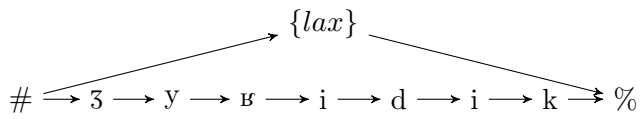
So a word would enter the derivation with high vowels underspecified for tense/lax and the rule (24) would apply.

(25) *juridique* 'juridical'

a.



b.



This is interesting since contrary to all the cases of harmony discussed in chapter 3, this is not a parallel feature introduced by a morpheme, but by a phonological rule. However other than this detail there is no reason to assume that there is anything else crucially different between the resulting harmony patterns.

The final process to discuss is a process of tensing that counteracts laxing. High vowels

[5]We have not yet discussed the representation of syllables, so this is stated as targetting C-final words. A separate rule would be required for CC-final and CCC-final ones.

are tensed and lengthened before /v, z, ʒ, ʁ/.

(26)

gʁi:v	'thrush (bird)'
e.gli:z	'church'
tsi:ʒ	'stem'
e.kʁi:ʁ	'to write'

This can be handled with a new rule.

(27) Pre-voiced-fricative tensing rule[6]

When a [+hi] segment x precedes a [+voi, +cont, -son] segment y, add +tense from x to y.

$$\text{X} \longrightarrow [+hi] \longrightarrow [+voi, +cont, -son] \quad \Longrightarrow \quad \text{X} \longrightarrow [+hi] \longrightarrow [+voi, +cont, -son], \ \{tense\}$$

Importantly when in apparent conflict, where a high vowel precedes a voiced fricative and also follows high vowels that could be affected by harmonythe result is both tensing of the final pre-voiced-fricative vowel *and* harmony over the previous high vowels, e.g. in the word /misiv/ 'letter', the result is [mɪsi:v] with a harmonized first vowel and a tensed final vowel.

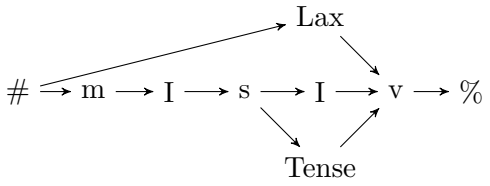
This can be accounted for in a traditional analysis, however it involves a number of analytical assumptions that have always been contentious. Laxing and harmony must be crucially ordered before tensing which counter-bleeds them such that the vowels are first laxed, and then the laxing of the last vowel is undone by tensing. This analysis involves opacity and a duke-of-york gambit.

[6] I will not discuss the lengthening part of this process.

UR	/misiv/
Laxing	misɪv
Harmony	mɪsɪv
Tensing	mɪsi:v
SR	[mɪsi:v]

The PROP analysis on the other hand follows from previous assumptions without any extrinsic ordering or duke-of-york gambit. The surface form follows from the assumption about nesting features from chapter 3.

(28) *missive* 'letter'



The Laxing rule adds a lax feature from the begining to the end as independently justified for harmony, and the tensing rule adds a smaller tense feature over the final vowel as independently justified for tensing. From nesting assumptions it follows that the final vowel will be realized as tense and only the first vowel will be realized as lax. The seemingly counterbleeding-like and duke-of-york-like outcome is the simplest possible outcome of the two processes.

We now have the tools to account for harmony patterns introduced by phonological rules and we see that they follow the same generalizations we have established before.

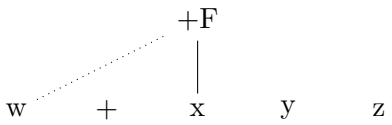
9.2 Regular alternations as partial overlap

In addition to the regular phonology on graphs as defined in the previous section, there are also new possibilities opened up by PROP to account for some phonological alternations. I will suggest here that some regular alternations that would traditionally be analysed with the help of rules may have a representational account.

One analytical advantage of non-linear phonology has been in attributing assimilatory

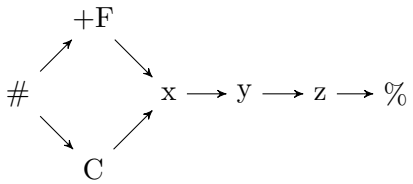
processes to geometrically simple spreading rules.

(29) Autosegmental assimilation

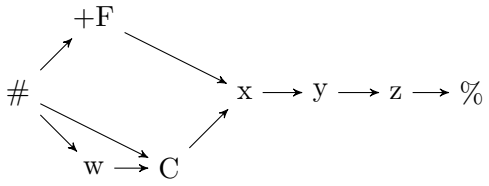


These processes can be given an equivalent PROP analysis by reframing the phenomenon in terms of putting morphemes partially in parallel to others, except the phenomenon is now purely representational and reliant not on an explicit assimilatory process, but on an explicit representation within the individual morphemes. The general logic would look as in (30), with a root surfacing with an initial [+F, +C] that is underlyingly split into two. If a prefix is specified to precede C, but is not given any sticky-end that will pick out the parallel {+F}, the result will be a partial prefix that is placed in parallel to {+F} which, based on the assumptions of chapter 3 entails that this {+F} will stretch over the duration of *w* and *C* if it is phonetically compatible.

(30) Partially-parallel affixation



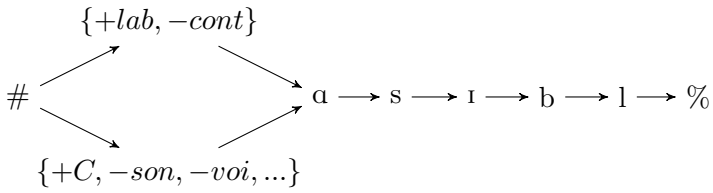
Partial prefixation of *w-*



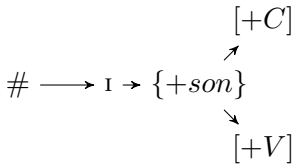
To take a concrete example, consider place assimilation of the prefix *in-* in *i**n**tolerable*, *i**m**possible*, *i[**ŋ**]capable*, etc. If we assume that English roots underlyingly separate the place feature from the other consonantal features as in (31), and the prefix *in-* is underlyingly as

in (32), assimilation will follow representationally.

(31) $\sqrt{possible}$

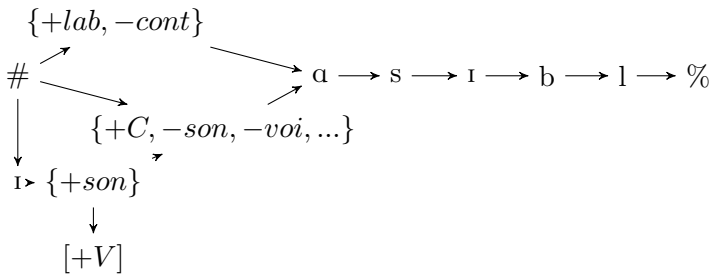


(32) *in-*



When (32) is affixed to (31) it gives the structure in (33) with the +son parallel to the +lab,-cont. With the extra minor assumption that English phonology fills in non-continuant sonorants as +nasal we have the assimilation taken care of by the fact that *in-* was put in parallel to the Place and continuancy features of the root-initial consonant.

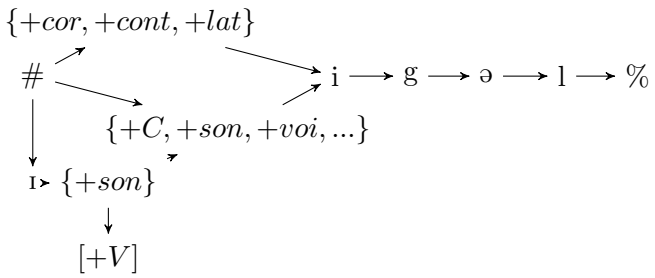
(33) *im-possible*



The assumption that the prefix consonant is not inherently +nasal helps account for assimilation with /r/ and /l/ in *irregular* and *illegal*. The only constancy of the consonant

of the prefix *in-* is its being a sonorant.

(34) *il-legal*

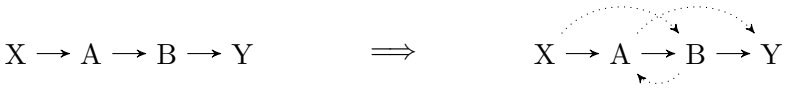


In the V-initial case, we simply a default insertion rule, or for underspecified consonants to surface as coronal by default.

9.3 Metathesis & Coalescence

Synchronic metathesis is an interesting type of phonological process in that it is complicated to state on strings. But a theory in which precedence can be directly manipulated this is much more straightforward. For instance if A and B phonologically metathesize we could posit a rule of the form in (35). This was first suggested by Halle (2008) (in a different notation, as pointed out by Samuels (2010)) but it has the effect of causing metathesis of A and B by directly overwriting the order in which they must be traversed.

(35)



However I would like to suggest that metathesis phenomena have more to do with resolving parallel structures than active reversal in the phonology. And conversely I will propose that coalescence may be the reverse operation, putting segments in parallel.

9.3.1 Faroese

Consider an example of metathesis from Buckley (2011). In Faroese some words surface with [ks] sequences in the context of a following [t] and with [sk] sequences otherwise.

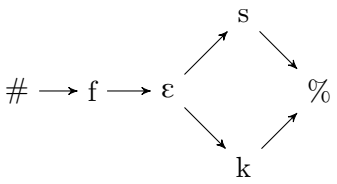
(36)

msculine	neuter	
fɛsk-ʊr	fɛks-t	'fresh'
rask-ʊr	raks-t	'energetic'
dansk-ʊr	daŋ ks-t	'Danish'

Buckley like everyone else analyses this as a reversal of /sk/>[ks]. That is he takes one order to be underlying and another to be derived. With strings this is the only possibility, as everything need to be ordered throughout the derivation.

But with PROP there is a new option, namely the two segments could be underlyingly unspecified for order.

(37) $\sqrt{fesk - /feks-}$



From this underlyingly underspecified order the two surface orders would be derived contextually. This can be done in a number of ways, e.g. via a specific phonological rule adding a link from /k/ to /s/ in the context of a /t/, or from a language-specific phonetic convention[7], or maybe even from something universal about motor planning's preference for the order of certain events when their order is unspecified. Either way this allows for order alternations without operations of order reversal: rather than starting from an order and derive the other, we can start from no order and derive both. This is desirable because for phonology on strings, operations capable of reordering segments are a big departure from the

[7]I will use this vague term to refer to anything not-strictly-linguistic that may be part of a speaker's knowledge when it comes to the usage of language.

rest of operations needed for rule-based phonology and inherently add a lot of complexity to the power of phonological rules. As Blevins and Garrett (2004) put it 'the reordering of sounds in metathesis has required extensions of otherwise highly restrictive phonological formalisms'. With PROP we may entirely dispense with re-ordering and therefore with re-ordering operations. Variable order in phonology is a very straightforward consequence of a representation in which things may be momentarily unordered with regard to each other.

Typologically, there do not seem to exist any case of synchronic metathesis that exchanges segments more than two places away (Canfield, 2016, p.38). If metathesis derives from such local lack of ordering we derive why that is the case. Metathesis in this PROP analysis is due to local underspecification for order.

9.3.2 Rotuman

Of course the patterns of metathesis can involve a bit more complexity than the examples above. Consider Rotuman as described and analyzed in Besnier (1987). Rotuman verbs have two forms, known traditionally as the *Complete* and *Incomplete*. The pattern is complicated, but the gist of it from a descriptive point of view is that the Incomplete is always predictable from the Complete and can be formed from it by reversing the last CV and applying a number of consistent rules to the resulting VV sequences as in (38-a). Notably, if the resulting VV sequence would be two identical vowels the result is a single vowel (38-b) (despite Rotuman allowing long vowels). And sometimes the two vowels coalesce as in (38-c). As the details of the phonological processes affecting VVs are unimportant here, I will refer the reader who wants to know more to Besnier, particularly to Tables 1-3 which

summarize all the VV outcomes.

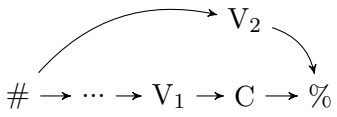
(38) Rotuman metathesis

	Complete	Incomplete	
a.	hepa	hyap	'broad'
	fika	fyɔk	'number'
	tife	tyɔf	'pearl shell'
b.	hanuju	hanuj	'tale'
	toto	tot	'blood'
c.	forɔsi	foræs	'to spread out'
	hose	høs	'oar'
	fuli	fül	'deaf'

The crucial alternation under Besnier's analysis is therefore between -V_1CV_2 and -V_1V_2C with some extra phonology happening in the latter forms.

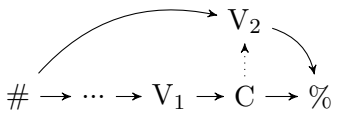
I would like to suggest a PROP analysis which is very close to Besnier's but crucially involves underlying parallel structure and puts V_1 and V_2 in parallel rather than in order. Specifically I would like to suggest that Rotuman forms underlyingly end as in (39).

(39) Underlying forms

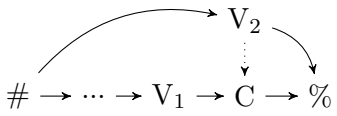


Forming the Complete and Incomplete from this underlying form boils down to adding one arrow, from C to V_2 (40) or from V_2 to C (41), respectively.

(40) Complete



(41) Incomplete



The form in (40) naturally creates an unambiguous V_1CV_2 sequence in the Complete. The Incomplete on the other hand puts V_1 and V_2 in parallel. This form immediately accounts for all cases where V_1=V_2 as in (38)[b]. These forms simply send a redundant representation to motor planning with two elements commanding to pronounce the same vowel in the same span. This explains why those sequences even need to be resolved when rotuman allows long vowels.

Cases of coalescence can be accounted for with explicit rules, but they can also be thought of a another strategy for the motor systems to deal with conflicting commands, namely gestural blending produced by averaging the two commands reminiscent of Smith (2018a,b, 2019). Even for the ones surfacing as glide-vowel sequences, there is some experimental evidence that complex nuclei may be analyzed as synchronous vowels (Marin, 2005).

Some amount of arbitrariness may have to exist to resolve some sequences, as there remains some asymetries, e.g. -aCe forms alternate with -εC while -eCa forms alternate with -yaC, so we cannot rely on a consistent resolution of parallel /e/ and /a/. This could require an explicit phonological rule, e.g. it would suffice to have a phonological rule that adds a link from /e/ to /a/ if they both precede the same segment and /a/ also precedes %. Or it could be that the surface segments are not all underlyingly identical: if the V_2 that surfaces as /e/ is -lo,-hi and the V_1 that surfaces as /e/ is -bk,-lo,-hi then the apparent symmetry of -aCe and -eCa in the Incomplete is broken.

Importantly the Incomplete form in does more than putting V_1 and V_2 in parallel, it puts V_2 in parallel to the whole form. This is desired for polysyllabic forms in which the incomplete affects all vowels as long as they are /u/ or /o/.

(42)

sukuni	sükün	'to pierce'
kukulufi	kükülüf	'tree sp.'
ʔopoti	ʔöpöt	'to follow'

Besnier's analysis in contrast requires a separate harmony rule that is morphologically

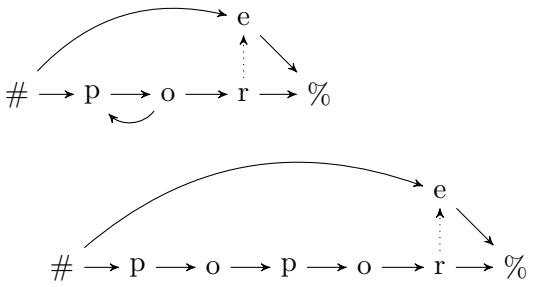
conditioned to only applies in this morphological context, a rather undesirable state of affair from the point of view of an independent phonology. In the PROP analysis this derives from the geometry.

Rotuman reduplication is also straightforwardly accounted for with the representations posited above. In reduplicated Incomplete forms, the effect of V_2 affects both copies, even in cases where harmony is not expected. This follows from the representation if we add a reduplicative loop as in (43), because there is a single V_1 that is equally affected by the coalescence rules prior to serialization of the loop.

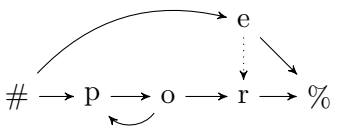
(43) Reduplicated forms

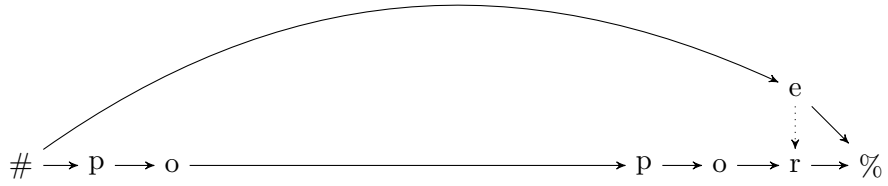
Root (in linear representation)	Red. Complete	Red. Incomplete	
/pore/	popore	pöpör	'suddenly'
/mami/	mɔmi	mɛmɛm	'disgustingly sweet'
/furuki/	furfuruki	fürfürük	'pimple'

(44) *popore*



(45) *pöpör*



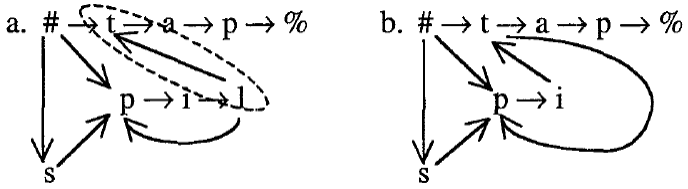


9.3.3 Indonesian

I have assumed in the previous section on Rotuman that coalescence amounts to segments coming to be in parallel. This fits particularly well with the analysis of vowels harmony in PROP given the data of Rotuman in which coalescence and some amount of morphologically-triggered vowel harmony seem to go together.

However Raimy (2000) already had an analysis of coalescence in terms of two nodes becoming one and inheriting all the precedence links that went in and out of either segment. for example in his analysis of Chumash, in which /l/ coalesces with coronals, Raimy posits an operation like (46) where the dashed lines surround the /l/ and /t/ that become a single /t/. As is visible in (46-b) the resulting /t/ combines all the arrows going in or out of either of the input segments.

(46) Chumash /l/+ [coronal] coalescence (copied from Raimy 2000, p.27)



There are many languages where Raimy shows that this analysis derives complicated effects in reduplication in which a coalesced segment affects both copies in reduplication. For example Indonesian has a few prefixes whose behavior descriptively involve assimilation and coalescence, including the active prefix /*məN-*/, which in modern Indonesian marks active verbs. Descriptively the /N/ of the prefix usually disappears, assimilates to the following segment or defaults to /ŋ/, but in the case of voiceless stops the result is a nasal

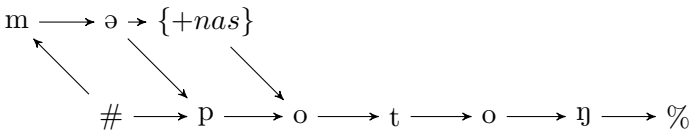
of the same place of articulation as the voiceless stop.

(47) Indonesian active prefix (from McCarthy and Cohn 1998)

		root	prefix+root	gloss
a.	b,d,g,c,j	bantu	məmbantu	'help'
b.	m,n,ŋ	masak	məmasak	'cook'
		nomor	mənomor	'number'
		ŋəri	məŋəri	'horrified/ing'
c.	l,r,w,y	latih	məlatih	'practice'
d.	p,t,s,k	potoŋ	məmotoŋ	'cut'
		tulis	mənulis	'write'
		kata	məŋata	'word/say'
e.	vowels, h	isi	məŋisi	'fill'
		atur	məŋatur	'arrange'
		hargai	məŋhargai	'value'

So far this is not a problem for the parallelization story. It is straightforward to specify an affix so as to attach like (48).

(48)



However the interaction of this prefix and its coalescence with the intensive/repetitive reduplication lends itself slightly better to Raimy's version of coalescence. As shown in (49)

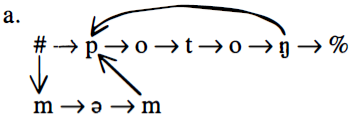
that the coalesced segment appears in both copies.

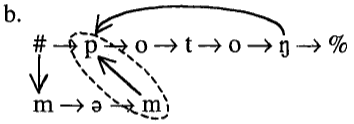
(49) Indonesian intensive/repetitive (from Raimy 2000, p.99)

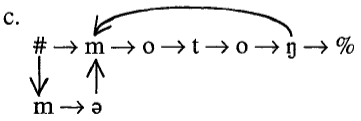
root	intensive/repetitive	gloss
potoŋ	mə-motoŋ-motoŋ	'cut'
tulis	mə-nulis-nulis	'write'

For raimy this is easy to account for as in (50). Coalescence happens prior to serialization and the resulting segment inherits from the original /p/ to be in the reduplicated loop.

(50)

a.


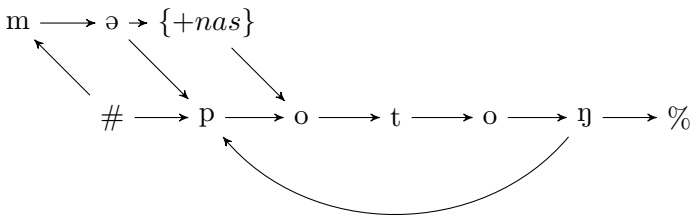
b.


c.


d. #→ m→ ə→ m→ o→ t→ o→ ŋ→ m→o →t →o →ŋ →%

This is not an immediate effect of adding reduplication to the form with parallel structure above as in (51). Given the assumptions of §7.6 and the similarity with the Sye pattern in §7.4 we would precisely expect this form to surface as **məmotoŋ-potoŋ*, the exact form that Raimy's analysis is meant to rule out.

(51) **məmotoŋ-potoŋ*



We could imagine that the reduplication morpheme could be specified to add two back arrows, one to /p/ and one to /{+*Nas*}, but since there isn't much structurally in common between those two nodes of the graph this reduplicative affix would need to be rather convoluted, and then we lose the nice natural explanation that Raimy offers in terms of coalescence feeding serialization.

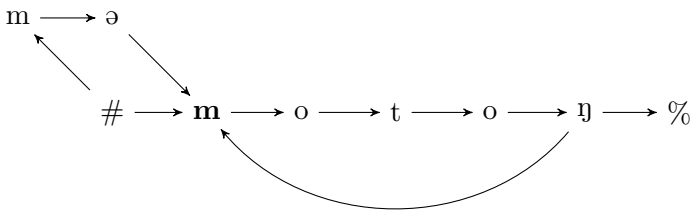
There are multiple ways out of this that would preserve Raimy's insight in PROP. A simple one would be to posit that there are two processes that can lead to what we call coalescence: Raimy's node conflation idea and the parallelization we have been exploring.

Another possibility would be to modify/expand Raimy's coalescence to apply to parallel structures. Consider an operation that could take parallel structures and combine them into a single segment.

(52) Parallel Coalescence

This would allow us to adapt Raimy's analysis with coalescence feeding the resolution of reduplication into a PROP format by applying Parallel Coalescence to the structure in (51), yielding (53).

(53)



One possible value for this operation is for the readers who may find the PROP analysis interesting but are not on board with parallel structure in the output of phonology, as this

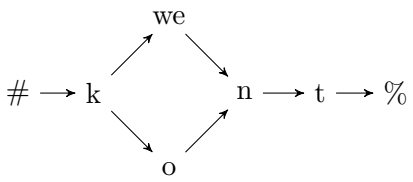
could help derive strings from the parallel streams we have posited.

(54)

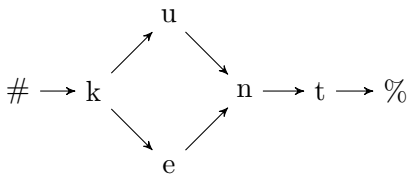
9.3.4 Spanish root allomorphy

In chapter 6 I proposed an account of the Spanish *kwent-/kɔnt* suppletion based on an underlying root like (55) with the two options [we] and [o] fully separate. But in light of this section's analyses of metathesis and coalescence, I propose we could instead posit (56).

(55) $\sqrt{cont}$ (according to ch. 6)



(56) $\sqrt{cont}$ (updated)



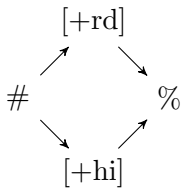
With this form, the allomorphy would not consist of de-linking either the upper path when stressed or the lower path when unstressed; it would rather consist of adding an arc that orders the /u/ before the /e/ to yield [we] when stressed, or leaving the two in parallel to coalesce into [ɔ] when unstressed. This additive phonological rule dispenses with the need for the precedence-relation-deleting rule we had to posit in that chapter.

9.4 Complex segments

We have seen already seen in chapter 3 how complex forms in the phonology could consist of simultaneous components set in parallel and sent as such to the phonetics to performed simultaneously by the articulators or heard simultaneously in perception such that a surface

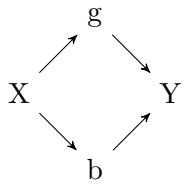
segment {+rd,+hi} may have the following form in phonology.

(57) Possible phonological form giving rise to surface {+rd,+hi}.

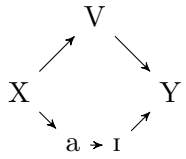


It is easy to see how PROP may be useful to describe complex segments like doubly articulated consonants and contour segments qua complex segments as in (58) and (59), respectively. These analyses simply make use of the representations made available for free in PROP

(58) Possible representation giving rise to [g͡b]



(59) Possible representation giving rise to [a͡i]



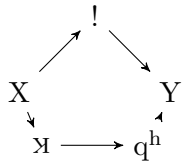
A specific analysis of complex segments that can be adapted to PROP is the unique and highly insightful analysis of Taa clicks in Bradfield (2014). Bradfield argues that Taa clicks are 'concurent clusters', clusters of segments that occur partially in parallel in time. I will not go over the arguments for this view based on synchronic phonology, learnability, and laboratory phonology and only describe the analysis.

Bradfield introduces a new notation (X⊗Y) signifying that X is concurrent with Y. Bradfield proposes to decompose Taa clicks into 'Pure click phonemes' /ʘ ǀ ǃ ǁ ǂ/ and

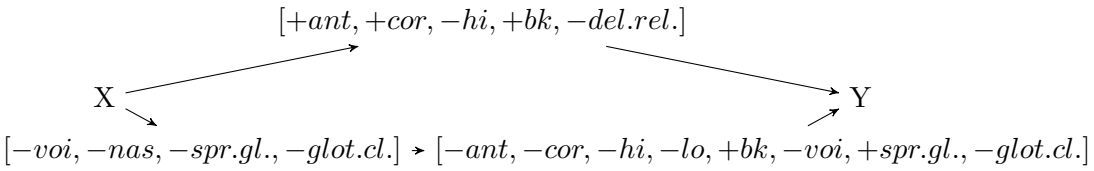
'accompaniement phonemes' /ʞ ʞ̟ ʞʰ ʞ̟ʰ ʞ' ʞ̟' ʞ̃ ʞ̟̃ / which combine with other non-click consonants to generate the wide variety of Taa clicks through concurrent clusters. For instance Bradfield proposes that !q^h is underlyingly (!⊗ʞq^h). This is a concurrent string of one click phoneme /!/ combined with a concurrent string of two phonemes, the accompaniement / ʞ / and the non-click phoneme /q^h/.

This organization of phonemes is interesting: it involves some features being in parallel to others that are linearly ordered. This would be difficult to encode in most systems, hence why Bradfield had to resort to inventing his new ⊗-notation. But it is very straightforward to represent in PROP as in (60) using Bradfield's symbols, or (61) featurally.

(60) Taa (!⊗ʞq^h) symbolically



(61) Taa (!⊗ʞq^h) featurally

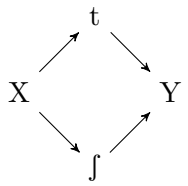


PROP therefore provides a way to represent Bradfield's analysis of !Xõó clicks that maintains his analysis in terms of concurrency vs. sequence, a distinction that follows naturally from PROP.

Another type of complex segments is affricates. We could posit a PROP representation such as (62). The pronunciation of this structure would surface as a contour as a necessary result of the impossibility to pronounce both segments simultaneously. It is not necessary for the two parallel nodes to be fully specified segments, it is sufficient that they contain some incompatible features like −*continuant* and +*continuant* (or −*continuant* and +*strident*

following Clements (1999)).

(62) Possible representation giving rise to [t͡ʃ]



The question that needs to be asked then is how would motor planning deal with such incompatible commands scheduled between the same pair of commands X and Y. It does not seem that there is any optionality in the order of the [t] and [ʃ] portions of an affricate [t͡ʃ]. A speculative but reasonable assumption would be that when nothing else determines the order of two segments their relative will be left to whatever is easiest to schedule for phonetics. If the muscle movements of a stop are faster to prepare than the muscle movements of a fricative –a reasonable claim since a fricative requires a more delicate aperture of the constrictor– this might be all we need to say. This is fundamentally a scheduling conflict: two segments are competing for use of the articulator, and motor planning is in charge or deciding which one can go first. If we imagine that the decision is made on the basis of the time to process the segment by scheduling the faster segments before the slower ones, we might derive the facts of affricates.

However empirical facts about other complex segments do not lend themselves to such an analysis. Glottalized consonants for instance would lend themselves to an analysis in terms of a consonant with a parallel glottal stop, but it appears that the timing between the glottal and suprasegmental events can vary from language to language and can even be allophonically determined within a language. Howe and Pulleyblank (2001) describe Yolumne and Kwak'wala whose glottalized sonorants are post-glottalized in codas but pre-glottalized in other contexts, compared to Sṁalgyak, Montana Salish, and Lai whose glottalized sonorants are always pre-glottalized. It therefore seems to be the case that if glottalized segments are to be analyzed as parallel complex segments then, unless a universal phonological conditioning can be found for all pre- vs. post-glottalized consontants, it seems that sometimes the parallel complex segments are under-determined by the fully parallel notation above

and must be handled by language-specific rules or conventions.

9.5 Ineffability and paradigmatic gaps

An interesting phenomenon of morphology is that of ineffability or paradigmatic gaps, slots in the paradigms of a language where no combination of a root with any affix is acceptable to native speakers. This phenomenon is already puzzling at first sight in light of Language as a productive system, but further inquiry also shows multiple difficulties relating to the acquirability of a gap in light of the problem of negative evidence, or to the nature of *how* it is that one can know of a gap.

A classic example (dabrowska2001learning, Gorman and Yang (2019) is that of Polish masculine genitives. Polish has two forms of the masculine genitive suffixes which are not phonologically predictable: *-a* and *-u*, but some roots cannot take these suffixes. Some roots like *balon* cannot take either suffix, and cannot be used in the genitive whatsoever. This contrasts with indeclinable roots like *guru* which also cannot take either suffix, but can surface without either in the genitive.

(63)

nom.	gen.	gloss
liść	liść-a	'leaf'
dom	dom-u	'house'
balon	*balon-a *balon-u	'balloon'
guru	guru	'guru'

Gorman and Yang's acquisition-based analysis, embedded in a specific morphological model that is not relevant to this thesis, is that neither suffix is sufficiently common in the language to reach a point where the language user will treat them as productive. But an equally important question is: what is the nature of the ban itself? It seems strange to assume that the learner acquires explicit **balon-a* and **balon-u* constraints, and hence Gorman and Yang offer a non-generation analysis: the two suffixes *-a* and *-u* are each

specified to attach to a finite list of roots and neither is truly a default.

This analysis can be recast in PROP with the tools used for MCA in chapter 6. The roots would be stored as (64), and the affix as in (65). Crucially, *ballon* and *guru* lack any diacritic that (65) can pick up, and *balon* lacks an underlying path to %.

(64)

$$\# \longrightarrow \mathrm{l} \longrightarrow \mathrm{i} \longrightarrow \mathrm{c} \rightarrow \widehat{\mathrm{tc}}_{\mathcal{A}}$$

$$\# \longrightarrow \mathrm{d} \longrightarrow \mathrm{o} \rightarrow \mathrm{m}_{\mathcal{U}}$$

$$\# \longrightarrow \mathrm{b} \longrightarrow \mathrm{a} \longrightarrow \mathrm{l} \longrightarrow \mathrm{o} \longrightarrow \mathrm{n}$$

$$\# \longrightarrow \mathrm{g} \longrightarrow \mathrm{u} \longrightarrow \mathrm{r} \longrightarrow \mathrm{u} \longrightarrow \%$$

(65)

$$\begin{array}{ll} [\mathcal{A}] \rightarrow \mathrm{a} & \searrow \\ & \% \\ [\mathcal{U}] \rightarrow \mathrm{u} & \nearrow \end{array}$$

The idea is that when affixed to a form with an $\mathcal{A}$ or $\mathcal{U}$ feature the affix will be able to find this feature and add a path to %, but in the case of $\sqrt{ballon}$ and $\sqrt{guru}$ it will not find either feature. this means that in the genitive of *balon* there will be no path from # to % whatsoever. This contrasts with the case of indeclinable nouns like *guru* in which there is a path in the underlying form, so even though there are no $[\mathcal{A}]$ or $[\mathcal{U}]$ features for the affix to attach to, the form will still be pronounceable in much the same way as the *-en* affix discussed in 5.3.9. The only new thing this analysis requires is the idea of roots which do not underlyingly have a path from # to %. Given the assumptions so far, there is no reason to posit any restrictions on the valid graphs allowed in the theory, and in this

light disconnected graphs are allowed by default and it would take a special stipulation to prevent them. I propose that there is no reason to ban them and they in fact serve to explain paradigmatic gaps like in Polish: some roots lack a path from # to % and if the affix fails to provide one the combination of the two will simply be unpronounceable.

9.6 Templatic Morphology

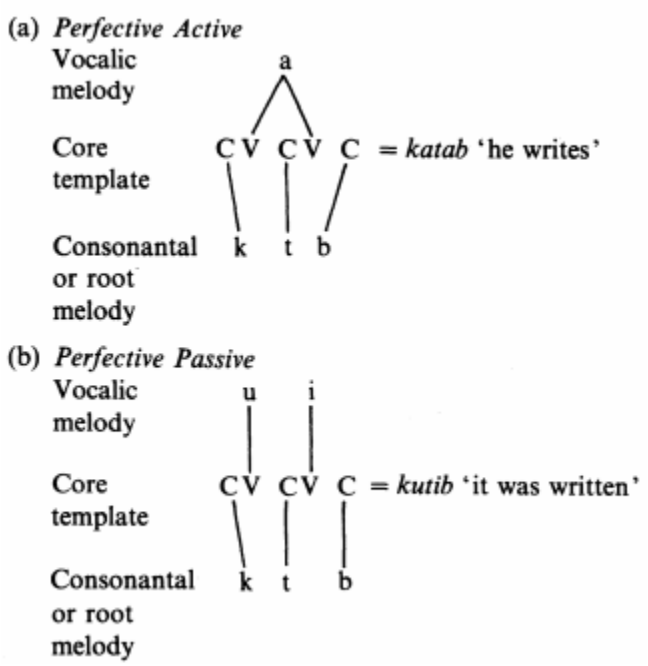
A major phenomenon that helped strengthen the position of Autosegmental Phonology's explanatory adequacy was its account of Templatic Morphology in Semitic. According to the now standard account of McCarthy (1981), the formation of Arabic *binyams* in (66) can be done by positing the CV-template of the *binyan*, the vowel melody of the aspect, and the consonant structure of the root to be three separate morphemes inserted in parallel

and joined by autosegmental principles as in (66).

(66) Classical Arabic *binyans* from McCarthy (1981, p.385)

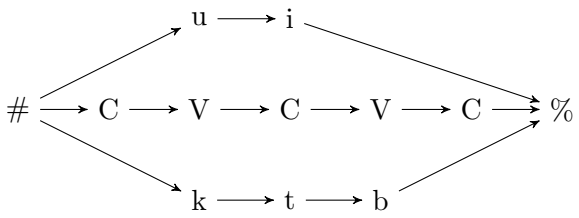
	Perfective		*Imperfective*		*Participle*	
	Active	Passive	Active	Passive	Active	Passive
Triliteral Roots						
I	katab	kutib	aktub	uktab	kaatib	maktuub
II	kattab	kuttib	ukattib	ukattab	mukattib	mukattab
III	kaatab	kuutib	ukaatib	ukaatab	mukaatib	mukaatab
IV	ʔaktab	ʔuktib	uʔaktib	uʔaktab	muʔaktib	muʔaktab
V	takattab	tukuttib	atakattab	utakattab	mutakattib	mutakattab
VI	takaatab	tukuutib	atakaatab	utakaatab	mutakaatib	mutakaatab
VII	nkatab	nkutib	ankatib	unkatab	munkatib	munkatab
VIII	ktatab	ktutib	aktatib	uktatab	muktatib	muktatab
IX	ktabab		aktabib		muktabib	
X	staktab	stuktib	astaktib	ustaktab	mustaktib	mustaktab
XI	ktaabab		aktaabib		muktaabib	
XII	ktawtab		aktawtib		muktawtib	
XIII	ktawwab		aktawwib		muktawwib	
XIV	ktanbab		aktanbib		muktanbib	
XV	ktanbay		aktanbiy		muktanbiy	
Quadriliteral Roots						
QI	daḥraj	duḥrij	udaḥrij	udaḥraj	mudaḥrij	mudaḥraj
QII	tadaḥraj	tuduḥrij	atadaḥraj	utadaḥraj	mutadaḥrij	mutadaḥraj
QIII	dḥanraj	dḥunrij	adḥanrij	udḥanraj	mudḥanrij	mudḥanraj
QIV	dḥarjaj	dḥurjij	adḥarjij	udḥarjaj	mudḥarjij	mudḥarjaj

(67) Autosegmental analysis of Classical Arabic (Haile and Mtenje, 1988)



PROP is capable or recapitulating the gist of this analysis by simply positing three parallel streams as in (68). Following the assumptions made so far this would be sufficient to account for the pattern of contrasts of Classical Arabic.

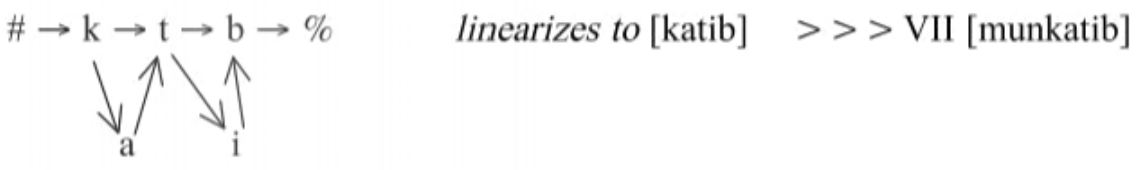
(68) *kutib*, 'it was written'



This is very straightforward, but it is worth mentioning because Raimy (2007) had already proposed a way to handle templatic morphology in Multiprecedence without using

parallel streams. Raimy takes the vowels to be explicitly placed onto the root.

(69) Derivation of Binyan VII (Raimy, 2007)



Raimy's approach departs from the classical analysis. It require the CVCV pattern of binyams to emerge as an accidental side-effect of the explicit positioning of vowels rather than to come as their own templates. This loses the generalization offered in the autosegmental analysis. The PROP analysis on the other hand maintains the classical analysis without any further assumptions.

9.7 Parallel features not pronounced throughout the form

An interesting type of variable-position affixes is also attested under the name of 'featural affixation'. Consider the following Chaha data from Akinlabi (1996). The generalization is that a third person singular masculine object is marked with labialization of the rightmost labializable consonant, meaning a labial or a non-palatalized dorsal. In the absence of such

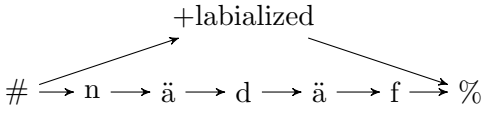
a segment the form remains unchanged.

(70) Chaha object agreement

without object	with 3sg.m. obj.	gloss
dänäg	dänäg^{w}	'hit'
nädäf	nädäf^{w}	'sting'
näkäb	näkäb^{w}	'find'
näkäs	näk^{w}äs	'bite'
käfät	käf^{w}ät	'open'
bäkär	bäk^{w}är	'lack'
qätär	q^{w}ätär	'kill'
mäsär	m^{w}äsär	'seem'
mäk^{y}är	m^{w}äk^{y}är	'burn'
sädäd	sädäd	'chase'

The first part of the account is to analyse the labialization as a parallel affix containing a +labialized feature creating structures like (71). This immediately derives the forms in which there is one or no labializable segment.

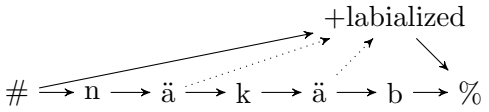
(71) *nädäf^{w}*



The PROP account could stop here. The above is sufficient for all the existing contrasts of Chaha, as in the cases of Mende or Siane in the previous chapter. The only question we could ask is why is the labialization limited to the final labializable segment, rather than being realized as labialization across all labializable segments of the form. For instance why

is the form [näkäb] labialized as [näkäb^w] and not *[näk^{w}äb^w]. Again I suspect that this could be either language-specific phonetics or a late phonological rule. The latter could simply consist of a rule adding a path from segments preceding labializable segments to the [+labialized] feature.

(72) *näkäb^w*



However in general I would maintain that the details of the phonetic realization of a form like (71) is not necessarily the concern of PROP. All that (71) specifies is that the feature *+labialized* follows the beginning of the word and precedes the end of the word and [näkäb^w] satisfies this requirement. PROP underspecifies the exact details of linearization.

9.8 Featural parafix in Mokulu

The parallel affixation predicted by PROP has so far mostly been discussed in a few forms: word tones, vowel harmony, single features, and CV templates. One pattern of parallel affixation that did not fit in any of these categories is that of Mokulu as described in Roberts (1994). When comparing the completive aspect to the citation form of verbs, Roberts notes that 'the completive is uniformly characterized by an initial voiced consonant and a high vowel' and attributes this to a pair of floating autosegmental features [+voice][+high]. According to Roberts this is a fully regular pattern and the only major idiosyncrasy is that

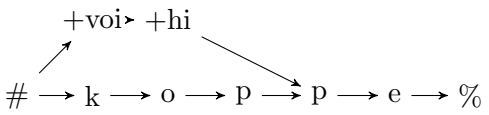
initial /t/ is immune to this voicing.

(73) Mokulu from Roberts (1994, p.95)

Citation form	*Completive*	*Gloss*
pélkè	bílkè	*to chat, converse*
báàtè	bíitè	*to lack*
dîrse	dîrse	*to lean on*
kóppé	gúppé	*to swim*
gárkè	gírkè	*to practice divination*
cààcé	jìicé	*to deceive*
jíidè	jíidè	*to add*
séllè	zíllè	*to appease, console*
zòòríkè	zùùríkè	*to expect*
èèpé	ìipé	*to fill a receptacle*
óópé	úùpè	*to be left over*
lékkè	líkkè	*to live*
nààbé	nìibé	*to work*

Roberts's analysis can be straightforwardly translated into PROP with an affix that carries the two features.

(74)

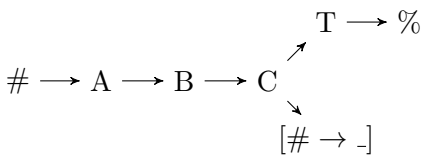


This type of small non-spreading featural affix of more than one feature seems rather rare, cross-linguistically but PROP handles it straightforwardly. It is one more example of the type of rare word-formation patterns that can be easily accounted for in PROP.

9.9 Peak Delay

In ch. 3 we saw how the phenomenon of tone donation could be handled in PROP with forms such as (75) in which the tone is both independent from the segmental features of its morpheme and simultaneously linearly ordered, two things that autosegmenta lrepresentations cannot do at once.

(75)



This analysis can be interestingly connected to the Peak Delay analysis of apparent tone shift in some languages. For instance consider Kikuyu as described in Kaplan (2008, citing Clements 1984). The interesting pattern is that although *rɔr* and *mo* are underlying toneless, the morpheme *ma* causes them to surface with a high tone. The traditional autosegmental analysis is that *ma* comes with a H tone, which shifts to the following vowel.

(76)

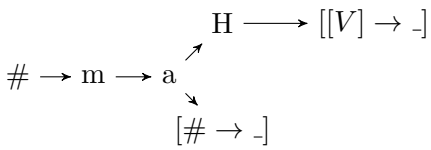
to rɔr aɣ a	'we look at'
to mo rɔr aɣ a	'we look at him/her'
to ma rɔ́r aɣ a	'we look at at them'
má rɔ́r aɣ a	'they look at'
má mó rɔr aɣ a	'they look at him/her'
má má rɔ́r aɣ a	'they look at them'

Studying a similar phenomenon in Chichewa, Myers (1999) found an interesting phonetic generalization: the f_0 peak of the tone is predictably aligned not with the vowel it happens on, but with the previous one. Kaplan (2008) proposes that there is in fact no tone shift in the phonology of Kikuyu, rather the tone is still associated with the vowel of its original morpheme, but phonetic implementation allows the exact realization of alignment to be parametrizable such that a tone associated with a vowel can be set as aligning the center of the vowel with the peak of the tone, or as aligning the center of the vowel with the onset of the tone rise. In the latter case the peak may be on the next vowel despite being associated with its original vowel in the phonology.

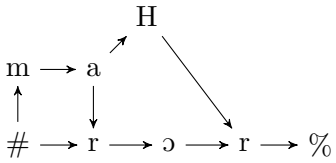
In PROP we can make sense of these phonetic findings without adding anything new. If tone donation works as in ch. 3, the form of the *ma* morpheme would be like (77) and

attach as in (78).

(77)



(78)

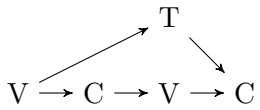


Crucially in such a representation, the donated tone is in fact 'associated' with the vowel that the tone immediately follows while it has no direct relation with the vowel it was put in parallel with. the information the phonology contains is that H follows [a] and precedes [r]; the fact that that puts it in parallel to [ɔ] is not strictly part of the representation. It seems perfectly reasonable then that in the phonetic implementation of such a structure the timing of the H tone will be more correlated with the vowel it does in fact follow in the representation than with the one it happens to be parallel with. As such in PROP we can derive the phonetic insight of Myers (1999) and Kaplan (2008) without having to add any parameter in the phonology. The phonetic implementation only has the precedence commands it gets when it comes to schedule the motor commands of speech, so if the donated tone is only specified in relation to the previous vowel then it will be scheduled in relation to that vowel.

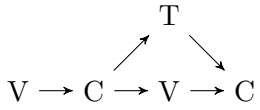
Hence in PROP the crucial contrast is not in whether alignment with the peak is ranked above alignment with the onset, but simply boils down to (79) vs. (80). In (79) the tone is scheduled after the previous vowel and it will therefore be aligned with it. In (80) on the other hand, the vowel and the tone both follow and precede the same segments, so they are

both scheduled in time after the same segment, and hence they will tend to align.

(79)



(80)



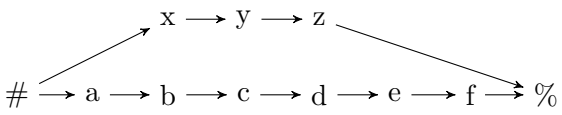
9.10 Self-placing affixes & Prosodic Optimization

In chapter 4, we saw examples of affix position determined in the phonology, either through the use of empty segments forcing parallel segments to align with them, or with explicit diacritics in the representation. And above we saw parallel affixes with some optionality as to where they could surface, to be determined either by phonology or phonetic convention. In all of those cases there was something explicit enforcing the compatibility of the two parallel streams: often one stream was 'deficient' in some way and need some sort of 'host' on which to surface, like the consonants lacking a +consonant feature in Afar or the individual features in Chaha or in all of the vowel harmony examples we have seen. And if the parafix consisted of full autonomous phonemes then their location needed to be 'guided' somewhat, either through a sticky end specifying their attachment point or as in the Siouan examples of unpredictable infixation through diacritics on the form.

But there is a logical option that is worth mentioning in addition to those, namely affixes consisting of full autonomous phonemes whose position is unspecified in the representation, allowing them to surface wherever they fit best, perhaps with some free variation,

imbricating themselves into a stem.

(81) abstract example of imbrication



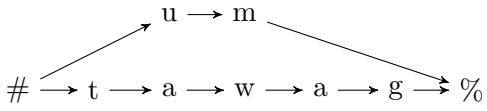
⇝ [abc-xyz-de]

This idea of infixes being inserted wherever they prosodically fit best is the standard analysis of infixation in OT. Recall the Taglog infixes from ch.2, repeated in (82). The OT analysis of this pattern is that constraints against codas and onset-less vowels are disfavouring **um-tawag* and favouring *t-um-awag* over it. According the the OT analysis the affix is infixed in order to prosodically optimize the surface form.

(82) Tagalog *um*-infixation (Kager (1999), citing French (1988))

alis	um-alis	'leave'
tawag	t-um-awag	'rewarded'

In contrast the PROP analysis of this pattern in ch.2 had sticky-ends directly placing the affix before the first vowel, which derives the same pattern in more explicit terms. But if PROP were to borrow Prosodic Optimization as a phonetic scheduling principle, we could replace the explicit sticky-end analysis with a parafix like (83) and leave the ordering entirely up to the phonetic motor planning. If we posit the equivalent of constraints against codas or onset-less syllables in the phonetic, or even just a bias in favor of CVCV alternations, this could enforce the imbrication.



In his dissertation on infixation, Yu (2003) spends a major part of the second chapter arguing against Prosodic Optimization in the placement of infixes. Yu finds that all infixes can be specified for their point of attachment and that none of them require an optimization analysis. In fact he finds many infixes whose position does not optimize anything, or even creates marked structures. This is, in my opinion, a good argument against the type of

situation in (82). He also notes a lack of infixes whose placement actually varies significantly based on the structure of its host. The Tagalog infix above is very consistent in being placed before the first vowel of the noun. Yu concludes that a theory with explicit placement of infixes better accounts for the facts and that Prosodic Optimization is empirically inadequate.

There is however one language pattern that seems to be counter to Yu's generalization that Prosodic Optimization is never needed in the analysis, and unfortunately Yu does not discuss it in his dissertation although he mentions other infixes from the the same language. In Alabama (Muskogean), there is an interesting word-formation pattern that I will only sketch here. This example is doubly worth mentioning because on top of being a Prosodic Optimisation pattern, an analysis already exists that crucially depends on underlying unordered segments. Here is how (Montler and Hardy, 1991, p.2) introduce the facts of Alabama negation:

(83)

> The negative appears variously as a suffix, infix, or prefix with the shapes *-ki*, *-ikko*, *-ki-*, *-kii-*, or *ik-*. We shall show that each of these is derivable given (1) the phonological shape of the stem to which it is attached, (2) the underlying form /k/, / i/ which is unspecified for linear order, and (3) a general constraint on the shape of Alabama verbs to the effect that they must conform to a heavy-light word-final syllable frame.

This is too amenable to a PROP analysis to ignore here. And underlying form unspecified for linear order is what PROP is most uniquely capable of. I will refer the reader to

Montler and Hardy (1991) for a list of examples, I will only copy the generalizations:

(84) Alabama /k/,/i/ affix placement (copied from Montler and Hardy 1991, p.7)

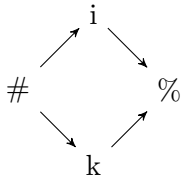
CV	**Prefix**	**/ik/**
(C)VVCV	**Infix**	**/kii/**
(C)VCCV	**Infix**	**/ki/**
(C)VC*k*V	**Infix**	**/ik/**
(C)VV*k*V	**Infix**	**/ik/**
(C)VCV	**Suffix**	**/ki/**
(C)VV	**Suffix**	**/ki/**
(C)VC	**Suffix**	**/ki/**

(85) Negative Placement (copied from Montler and Hardy 1991, p.9)

> (a) If the onset of the final syllable is /k/, then place before it.
> (b) If the stem already conforms to the Alabama verb insert /k/, /i/ into the rime of the penultimate syllable. (c) Elsewhere, place /k/, /i/ so as to conform to Verb Frame.

Contrary to Yu's claim, there does not seem to be an easy way to specify the position of this affix as a definite attachment point. there is no anchor point that we can single out as what the infix consistently precedes or follow. The position and order of the segments will be such that it optimizes the syllable structure of the word. In PROP the analysis would be to posit a parafix that puts both a /k/ and an /i/ in parallel to the whole form, and then the phonology of the language determines the position after that.

(86) Alabama negative affix



Just like in the discussion of surfcae optimization for allomorphy in 5.4.6, I mention this idea more as a logical possiblity than as a serious proposal and I will not push this idea any further. I am not at all convinced that this is the best analysis, even of Alabama. I find it mostly worth mentioning for its already using unspecified linear order. It might not be absolutely necessary for this account to work to appeal to the equivalent of Prosodic Optimization. There could be a series of rules that explicitly add the arrows between the /k/, /i/, and the stem necessary to derive the pattern. Some arbitrariness is already needed to handle the stems with final onset /k/.

9.11 Above the 'word': graphs all the way up

The discussion so far has been restricted to the word and some clitics. However I take for granted the following two claims that have been made previously in the literature:

- Syntax-all-the-way-down: There is not special word-building morphology and the mechanisms responsible for building syntactic structures also serve to assemble morphemes together (Lieber 1992; Halle and Marantz 1993, among many others).
- There is no such things as words: the notion of word does not have a special theoretical status. (Marantz, 1997)

Given the assumption that the word level is not special, it would be strange if the graph-based word formation I posited in this thesis was arbitrarily restricted to the traditional word. So it would be useful to discuss the application of PROP above the 'word' level.

There are independence arguments to think that the phenomena we have discussed in terms of PROP are not restricted to the word level. Consider first reduplication. Lidz (2001) shows that echo-reduplication in Kannada can target chunks much larger than single words. The semantics of 'X and X-like things' conveyed by full reduplication, replacing the first CV of the second copy with *gi(i)-*. Lidz provides examples of reduplication copying anything from single roots (87) and functional items (88), to entire VPs (89) and PPs (90).

(87) **ooda-giida** beeDa

run-RUN PROH 'Don't run or do related activities'

(88) **meelee-giilee**

above-RED

'Above and the like'

(89) nannu **baagil-annu much-id-e giigilannu muchide** anta heeLa-beeDa

I-NOM door-ACC close-PST-1S RED that say-PROH

'Donât say that I closed the door or did related activities.'

(90) pustav-annu **meejin-a meele giijina meele** nooD-id-e

book-ACC table-GEN on RED see-PST-1S

'I saw the book on the table and in related places.'

These examples suggest that however reduplication is done, its mechanics must be available at any point in the morphosyntactic structure-building system. It cannot be restricted to a word-formation module or otherwise exclusive to wordhood. Specifically if reduplication is done in the lines of Raimy (2000) with loops in the representation, then a graph-based representations must be in use all the way up in syntax.

The PROP affix required for this reduplication is something along the lines of (91), adding a path from the end of what it attaches to to the segment following the first vowel. But crucially it must be able to be affixed to the phonological output of very large syntactic chunks such as an entire VP.

(91) Kannada 'X and related things'

$$[\_ \rightarrow \%] \longrightarrow \text{g} \longrightarrow \text{i} \longrightarrow [\# \rightarrow C \rightarrow V \rightarrow \_]$$

Idsardi and Raimy (2013) distinguish *linearization* in the syntax from *serialization* of a multiprecedence graph in phonology. The proposal of this section amounts to positing that all linearization is serialization.

The existence of non-concatenative phenomena requiring 'morphological'-type machinery high in the syntax argue against the family of hypotheses that I will broadly group as Node-Ordering theories of linearization. The two main theories of order in syntax are

Head-Directionality Parameters (HDP) and the Linear Correspondence Axiom (LCA). The former puts order as a binary parameter putting the head before or after its complement. The latter even more strictly posits that the order between syntactic objects is determined by asymmetric c-command, yielding a universal head-initial word-order. Both of these purely concatenative theories will fail to explain any non-concatenative phenomenon in linearization. Reduplication was just given as an example but there are others we will see below.

Independent problems with the LCA have been pointed out multiple times in the literature. Uriagereka (2005, p.47) discussed the fact that the specific order produced by the LCA is arbitrary, as c-command could map onto precedence in either direction. Wojdak (2005, p.72-73) argues that this is a concpetual challenge for the idea. Wojdak also brings up empirical problems in that the LCA ruins analyses relying on differences in base order. She mentions the proposal that Dutch and Basque crucially differ in the base OV-VO order from Vicente (2004,2005). She also mentions the problem of analyses with rightward movement in Beerman, Leblanc, and van Riemsdiek (1997). Abels and Neeleman (2012) discuss the fact that some of the empirical predictions that have served as a confirmation of the LCA such as the derivation of Greenberg's Universal 20 by Cinque (2005) can be derived in other natural ways, and that the claim that the LCA can derive phrase structure is false. Further criticism has come from specialists of languages traditionally analyzed as head-final or specifier-final claiming failure of explanatory or sometimes even descriptive adequacy of LCA-compliant analyses of these languages, e.g. Cho on the problems it poses for Korean, Kural (1997) for Turkish, Rohrbacher (1994) for German and Yiddish, Bayer (1999) for Bengali, and Wojdak (2005, ch.3) for Nuu-Chah-Nulth among many others.

Non-concatenative phenomena are a further empirical problem that argues not only against the LCA, but also against HDPs. We have seen reduplication in linearization. A second phenomenon that argues for the mechanics of non-concatenative morphology applying all the way up syntactic structures is the case of endoclitics: the rare phonomenon of morphemes with clitic-like syntax in that they have syntactic scope over an entire phrase that they phonologically lean on, except that they surface infixed within a peripheral morpheme of their complement rather than as a proclitic or enclitic. This phenomenon is most

convincingly described in Pashto (Kopris and Davis 2005; Kopris 2009; Bögel 2010; Din 2013, among others) and Udi (Harris 2000, 2002). Examples of the person marker endoclitics in Udi are in (92). The two part of the discontinuous morphemes broken by the endoclitic are glossed with subscripts 1 and 2.

(92) Udi endoclitics (from Harris 2000)

a. pasčaɣ-un ɣar-en gölö bẹ-**ne**-ɣ-sa met'a-laxo
king-GEN boy-ERG much look$_1$-**3sg**-look$_2$-PRES this.GEN-on
'The prince looks at this for a long time'

b. kaɣuz-ax a-**z**-q'-e
letter-DAT receive$_1$-**1sg**-receive$_2$-AORII
'I received the letter.'

Endoclitics pose a problem to proponents to Node-Ordering Theories. Whatever accounts for linear order in Udi must have access to segments and be more powerful than something whose only options are 'before' and 'after'. In PROP however if order is only determined in the phonology via lexical items and their sticky-ends, endoclitics are unsurprising.

Yet another type of problem is the case of simultaneous linearization of syntactic items. The clearest case for this is from signed languages. Ever since Liddell (1980) it has been known that in American Sign Language non-manual markers typically occur over extended portions of the sentence. Liddel found that the topic marker was realized simultaneously to the entire topic. Many other examples have since been described. For example Jessica Harmon demonstrates the simultaneous articulation of non-manual adverbs, here a mouth movement resembling [po], simultaneous to the VP it modifies as in (93) (Harmon, 2016), and non-manual negation simultaneous to what it has scope over (Harmon, 2017). Asada (2017) echoes Harmon's finding about adverbs and VPs in Hong Kong Sign Language and further found examples of parallel conjunctions conveying simultaneity of the events.

(93)

po

HE COMMUNICATE

'He communicates a little.'

It has been known since Liddell (1977) and Baker and Padden (1978) that the scope of these non-manuals is the c-command domain of the functional item spelled-out as a non-manual, i.e. everything under its sister node. This simultaneity has led Harmon and Asada to argue in favor of a multidominance structure following Hornstein (2009) to account for the linearization, but no independent syntactic evidence is given for this structure; it is only required for them because of the limitations of Node-Ordering Theories.

In contrast PROP can maintain the classical c-command analysis and create parallel structures in the phonology. The adverb simply has syntactic scope over the VP, but its UR does not specify an ordering between its non-manual element and the phonological content of the VP. For PROP it is completely unsurprising that a morpheme can be put in parallel to another in sign languages since parafixation is needed for spoken languages too.

Pressing on this point, it is worth noting that multiple researchers have highlighted the simultaneity as an essential and fundamental difference between sign languages and spoken languages, taken as purely linear in organization. Frishberg (1975) puts it most succinctly with the claim that 'the essential character of language based on a sound signal is its sequential nature' and '[t]he corresponding essential character of a language based on a visual signal is simultaneity.' Aronoff et al. (2005) expand on this view with the thesis they call the 'paradox of sign language phonology'. I hope that the discussion so far has sufficiently shown that multiple phenomena of spoken languages benefit from simultaneous analyses. Linearity vs. simultaneity in morphology are both allowed and nothing we should consider the 'essential character' of one modality or another. Simultaneous morphology is allowed in sign languages because it is allowed in Language, and many phenomena instantiate this possibility in spoken languages too. Conversely unambiguous sequential morphology is also attested in signed languages, e.g. the agentivier suffix of ASL (Sandler and Lillo-Martin, 2006, p.64-66).

If one or the other modality strongly biases languages to converge more toward a simultaneous or sequential character, this will have to be more indirect than an 'essential

character'.

Vowel Harmony and Tone also contain phenomena that challenges the notion of word-hood. Even though Vowel harmony has been argued to be a universally word-bound phenomenon (usually employing some notion of Phonological Word), Downing (2018, citing Mutaka, 1995) shows that Kinande ATR harmony is phrasal and can spread to an entire DP, from the adjective to the noun, but not within VPs from a noun to a verb, making an analysis based purely on prosodic phrasing impossible. This is a problem for theories where word-hood is important, but in PROP this is simply a case where the noun is put in parallel to the $\pm ATR$ feature of the adjective. Similarly for tone, Marlo et al. (2015, p.8) discuss the fact that in Kuria tone assignment is a phrasal process. For verbs with the $/^4/$-melody, the melodic H is assigned to the fourth mora of the stem. If the stem is shorter than 4 moras then the tone surfaces on the following noun. I PROP both cases are simply the extension of what we have seen so far with a root being put with another root in a way that makes it parallel to a feature.

We can think of the 'syntax all the way down' proposal in the following way: we already need a structure-building operation to bring syntactic items together in syntax and the simplest theory is that the same operation is bringing morphemes together in words. Analogously and complementarily, PROP offers a data structure and mechanics for the construction of phonological structures in words, and the simplest theory is that these account for phonological material above words too. Syntax all the way down and graphs all the way up.

Node-ordering hypotheses were predicated on the assumption that phonology can only deal with linearized inputs. With the advent of Minimalism in particular the goal was to make linearization in syntax forced by bare-output conditions at PF in the sense of Chomsky (1995). E.g. Uriagereka (2005) sees the LCA as the minimally complex way to reuse a relation that exists in syntax and convert it into another to satisfy the PF requirement that its input be linearized.

But in PROP, this condition on PF is unnecessary. Phonology deals perfectly well with inputs lacking any ordering between them. PROP is self-linearizing. Vocabulary items carry the sticky ends that will place them onto a stem, and serialization will take care of

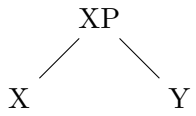
finalizing the final order. As such with PROP there is no need to say anything whatsoever in syntax about linear order. There is no order in syntax proper and there is no order imposed at PF either. Syntax is unordered hierarchical structure throughout.

There is one caveat however, namely all cases we have seen so far had the asymmetric form of one affix with one or more sticky-end attaching onto a static stem build from a root with a # and %. This can work without issue for all cases in which a head merges with a complement, and it can even work with roots merged with a complement if we allow roots to contain sticky-ends since nothing we said so far dissallows those, but it is not yet able to handle more symmetric cases involving Merge applying to two phrases, each with a root and affixes around them like (94). These cases are not easily analyzable as having one side containing sticky-ends.

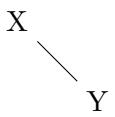
There are probably multiple ways to solve this issue and I will propose one grounded in an assumption that is increasingly common in the world of Morphology, namely that the input to vocabulary insersion is a Dependency Graph, as opposed to a Constituency Graph, following in particular Svenonius (2016) who uses Mirror Theory following Brody (1997, 2000); Svenonius and Bye (2011); Svenonius (2012); Adger (2012).

In this framework, heads do not project over their complements as in (94), rather they take their complement as a dependent as in (95).

(94)

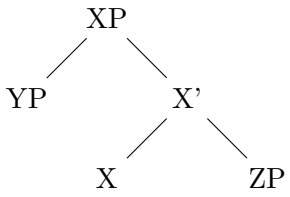


(95)

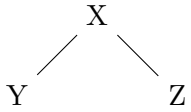


Crucially, structures that traditional X-bar theory treat as specifier-head-complement like (96) have two dependents as in (97).

(96)



(97)



Assuming that this is the structure on which spell-out applies we can resolve the problem we faces with Merging two phrases: in Mirror Theory two phrases can *only* meet as dependents of a head. Two phrases therefore never meet on their own, they always meet with a head. As long as this head contains the phonological material with sticky ends capable of attaching its dependents together, PROP will go without any issue.

Consider the spell-out rules in (98) applying to the dependency tree in (97). Bottom-up spell-out would first target Y and Z to transfer as (98-a) and (98-b) to the phonology, simply putting them together unordered as in (99). Then X would be targeted for spell-out to tranfer (98-c) onto (98), yielding (100) and the order [abcxyz]

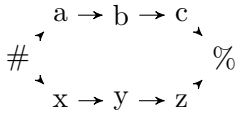
(98)

a. $X \longleftrightarrow /[c] \rightarrow [x]/$

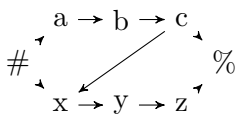
b. $Y \longleftrightarrow /\# \rightarrow a \rightarrow b \rightarrow c \rightarrow \%/$

c. $Z \longleftrightarrow /\# \rightarrow x \rightarrow y \rightarrow z \rightarrow \%/$

(99)



(100)

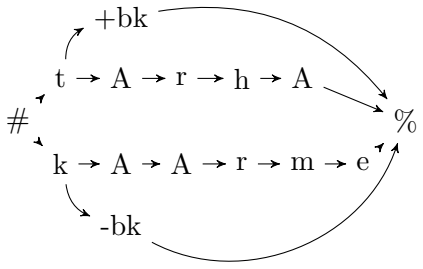


This spell-out order ensures that a head is always spelled onto any complex phrases merging together, and this head can be responsible for imposing an order between them. Or as in the case of ASL above for not imposing one and leaving them parallel. In the example above X is phonologically null and only imposes an order between the segments of Y and the segments of Z, but naturally it can also include overt segments to add between them, as well as a prefixed or a suffixed part, up to the complexity of the UR of X.

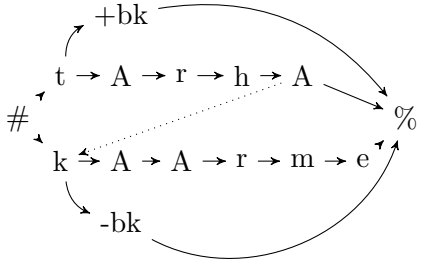
The structure in (100) immediately derives a number of useful facts. For instance consider the case of vowel harmony in compounds. In Finnish for instance, in the case of compounds with different backness specifications, the second member will control the backness of its suffixes. Välimaa-Blum (1999) gives the example of *tarhakäärme+ttä* 'of the garden snake', in which the suffix is front in accordance with *kaärme*, with complete disregard for the backness of *tarha*. This follows automatically from the assumptions adopted so far. In the form in (101) the +bk and -bk both scope over the end of the word and seem like they would equally spread to suffixes, but the addition of an order between the two roots as in (102) resolves the ambiguity as the scope of -bk is now fully nested within that of +bk, and thus by the Nesting Principle discussed in chapter 3 that one will win in that

scope, and hence that one will be realized over any subsequent suffix.

(101)



(102)

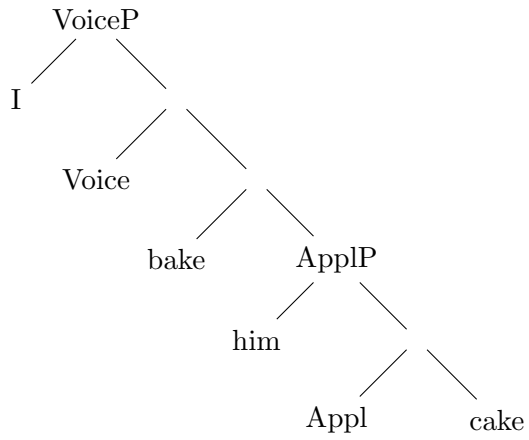


The example of the head in (100) above is unnatural in that it relies on knowing that the last segment of Y is c and the first of Z is x, but in a realistic derivation any segment can overtly end any phrase. A hack to solve this is to posit that all phrases of a certain type begin or end with a silent affix that introduces a feature onto the phonological chunk for the head to target.

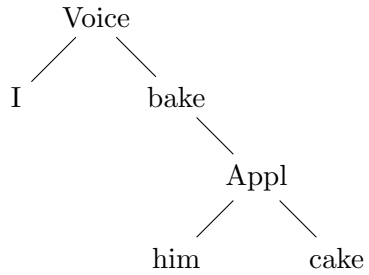
Consider the English double-object construction. Following Pylkkänen (2002), they have the structure in (103), with an applicative head joining the indirect and the direct

object. Converted into a Mirror-theoretic dependency structure it would look like (104).

(103) English low applicatives (Pylkkänen, 2002, p.19)

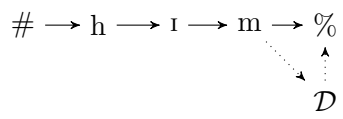


(104) Mirror-theory version of (103)

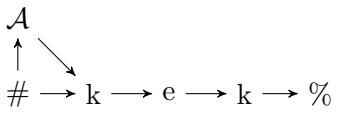


If the UR of Appl is to be responsible for ordering *him* and *cake*, something must be on there to be picked on by the sticky-ends of the applicative. A plausible way would be for the the dative case and accusative case are covert affixes, respectively a suffix and a prefix, which covertly introduce features, respectively $\mathcal{D}$ and $\mathcal{A}$, in the correct place on the form as in (105) and (106).

(105)



(106)

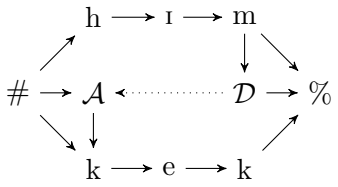


With this in place the applicative could be specified as in (107) and create the correct structure in (108)

(107)

$$[\mathcal{D}] \rightarrow [\mathcal{A}]$$

(108)



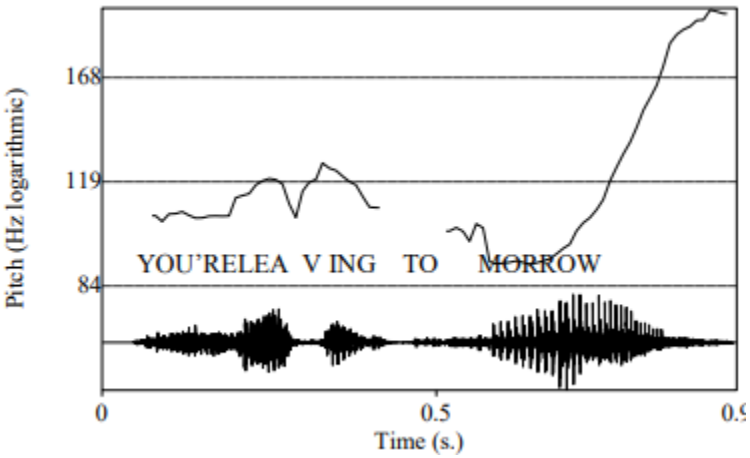
This is far from an elegant analysis. These features do little more than recapitulate syntactic information in the phonology. This is not an illuminating analysis, but simply a demonstration of how PROP could take over the task of linearizing syntax with only the phonological items' sticky-ends serving to order phonological material with regard to each other.

9.12 Intonation as morphemes

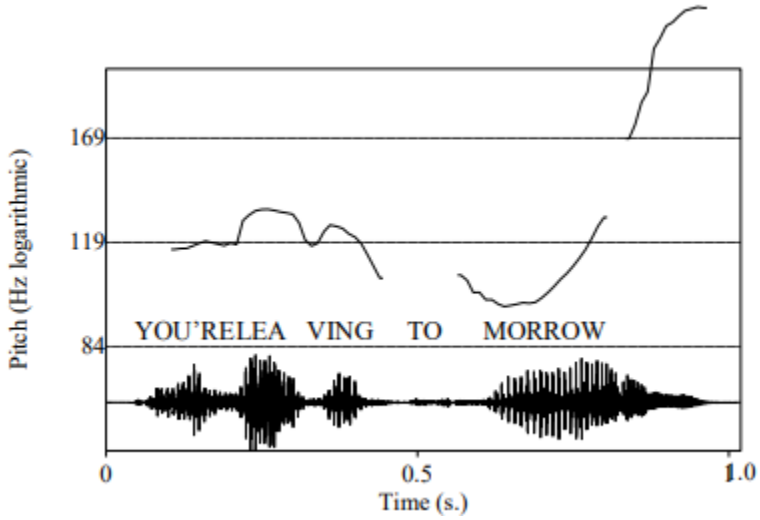
If PROP is extended to phenomena far above the 'word' level, its power to add parallel tonal structure can be applied to handle intonational melodies as morphemes. This was proposed before, e.g. by Cheng et al. (2000) for French Yes/No raising intonation, and more generally by Wakefield (2016) who proposed that intonation is fundamentally caused

by morphemes with scope over the whole sentence with meanings/functions comparable to sentence-final particles that are clearly morphemic, building his argument on the fact that many Cantonese sentence-final particles translate consistently into English intonational contours. For instance he proposes that the two yes/no interogative particles of Cantonese *aa4* and *me1* have a one-to-one relationship with subtly different yes/no question intonation contours in English with a mid-rising and a high-rising final contour respectively.

(109) Translation of aa4-suffixed sentence (copied from Wakefield (2016))



(110) Translation of me1-suffixed sentence (copied from Wakefield (2016))



In PROP we can directly capture this analysis. It suffices to posit a single syntactic head, common to Cantonese and English and very high in the syntax, which is spelled out

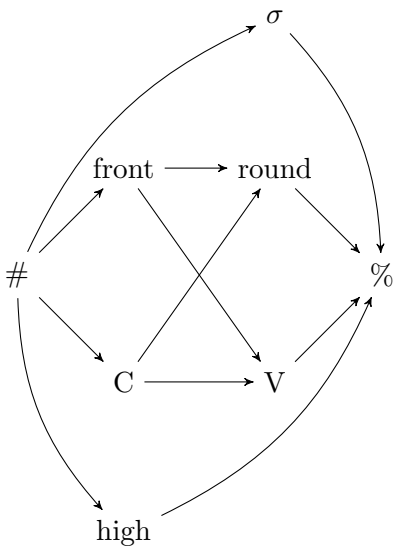
as enclitic in Cantonese and as a parafix in English.

9.13 Syllables and Stress

The notions of syllables and stress have been conspicuously absent from this dissertation. The role of the syllable in PROP deserves a much more detailed exploration than can be given here. Being all about precedence, PROP does not immediately mesh well with the standard understanding of the syllable as a hierarchical unit. There are a number of logical ways we could proceed. At one extreme we could join the ranks of syllable-skeptics and seek to eliminate the syllable as an explanatory unit of the theory (e.g. Samuels 2009), at another extreme we could abandon pure PROP and admit hierarchical syllables on top of the graphs needed for other phenomena.

Alternatively we could integrate syllables by just admitting them as a symbol of the theory without making any other claims about it. This was briefly suggested by Idsardi (2019) who proposed PROP structures such as (111) for the syllable [ju]. Here σ is just one symbol among all the others and whatever effects it has would come from its placement.

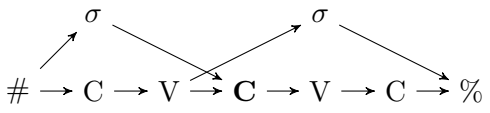
(111)



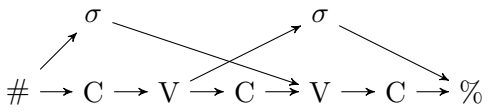
There are some benefits to this idea. For instance it allows for direct encoding of certain facts of syllable organization such as the notion of ambisyllabicity. For instance the differ-

ence between (112) and (113) is simply whether the middle consonant is only in the scope of the second syllable or in the scope of both. The latter might be what ambisyllabicity really is. Under this view, a syllabification algorithm would be about inserting σ's contextually, e.g. in parallel to every V.

(112) No overlap between syllables

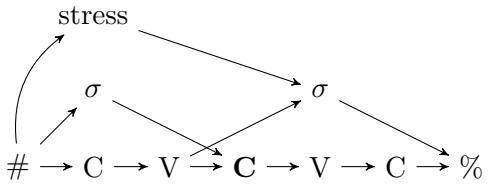


(113) Ambisyllabic Consonant



Stress could be handled in an analogous way with simple stress nodes added in parallel to syllabic and segmental nodes, e.g. in (114).

(114) No overlap between syllables



This proposal about stress has the advantage that it can potentially be used to translate bracket-based metrical-grid analyses such as Idsardi (1992). In Idsardi's system brackets are added via rules that create domains from which a Head can be projected. E.g. the analysis of Koya in (115) consists of five rules: 1) first add a bracket to the left of heavy element (here syllables), 2) add a left bracket on the left of the leftmost element, 3) project the leftmost element of each domain to the next tier, 4) add a left bracket on the left of the leftmost element ofthis new tier, and 5) project the leftmost elelement of this new tier onto yet another. This generates the Koya stress pattern of main initial stress and secondary

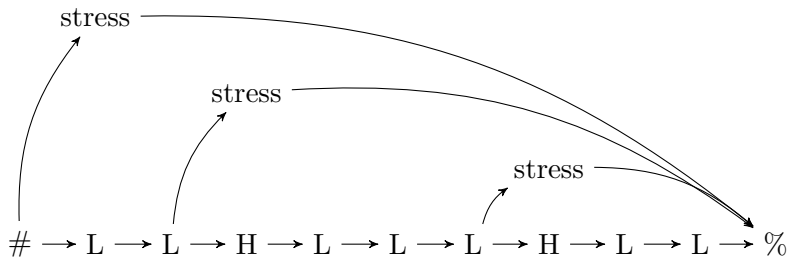
stress on every subsequent heavy syllable.

(115) Koya stress Idsardi (1992, p.15)

Line 0	Project:L	x x(x x x x(x x x L L H L L L H L L
	Edge:LLL	(x x(x x x x(x x x L L H L L L H L L
	Head:L	x x x (x x(x x x x(x x x L L H L L L H L L
Line 1	Edge:LLL	(x x x (x x(x x x x(x x x L L H L L L H L L
	Head:L	x (x x x (x x(x x x x(x x x L L H L L L H L L

We can convert this style of analysis by reinterpretating the brackets as 'there is a stress on this side'. Rather than rules adding a bracket that creates a constituent that will eventually project, we can skip these middlemen and talk of rules adding stress directly in parallel to heavy syllables and to the whole word. 'Projection' in this view would be about the subsequent realization of this stress at one location within its span in language-specific ways.

(116)

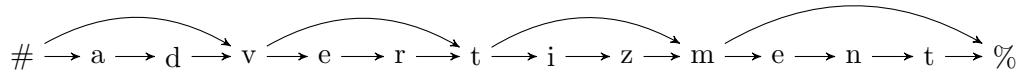


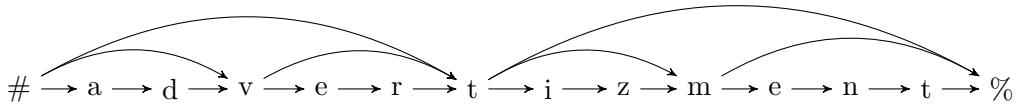
Yet another possibility would be to dispense with special symbols for syllables and employ only the notion of precedence like (117). A word like (117-a) would be syllabified

with the addition of arcs from onsets to onsets like (117-b), and then footed as in (117-c).

(117)

a. # → a → d → v → e → r → t → i → z → m → e → n → t → %

b. 

c. 

Although these arcs may appear to be be vacuous for introducing redundant precedence relations, the idea behind this representation would be to capitalize on the idea sketched in §9.9 above that precedence arcs regulate the timing between segments. The arcs added in (117) would have the effect of enforcing a kind of abstract rhythm between certain stretches of phonological material. Although the notion of stress-timed vs. syllable-timed languages from Pike (1945, p.34-36) has fallen out of favour since Dauer (1983), the presence of such arcs could contribute to the speakers' perception of isochrony in their language, even if this perception is not phonetically real. Under this view syllable effects and stress would then be computed on the basis of these structures with rules sensitive to preceding or succeeding more than one segment.

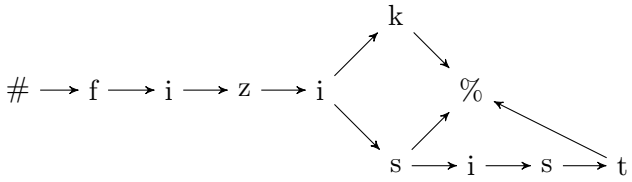
The question of how to handle prosodic structures in PROP is definitely an open question that requires further research.

9.14 Bracketing Paradoxes

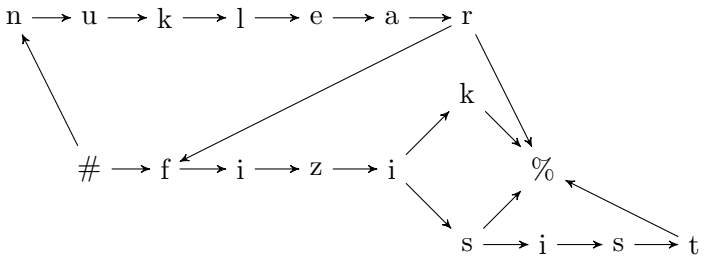
There are a number of so-called bracketing paradoxes that do not pose any problem anymore in PROP. Consider the classic example of *nuclear physicist*. The claim is that the semantics requires the analysis *[[nuclear physic]+-ist]* (a nuclear physicist is a specialist of nuclear physics, not a physicist who is nuclear) while the phonology requires *[nuclear + [physic+ist]]* because *physicist* is one word in which [k]~[s] allomorphy took place. But in PROP there is

no problem because allomorphy is a purely linear phenomena in the sense that it is entirely decided by what an affix attaches to and requires no notion of phonological word. If (118) is the representation of *physicist* then *nuclear physicist* can be as in (119) in which it doesn't matter whether or not *nuclear* is added before or after *-ist*; *-ist* simply follows the whole form and allomorphically selects the [s] by attaching to it, regardless of the internal syntactic complexity of the *nuclear physics* compound which word-formation is not sensitive to.

(118) *physicist*



(119) *nuclear physicist*



9.15 Marginal Phenomena

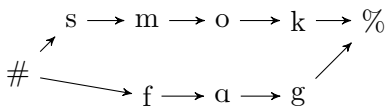
This final section of this chapter will cover marginal phenomena which PROP may be able to handle, but that I am not even convinced properly belong to a narrow theory of word-formation. The discussion is meant to be suggestive of the power of analysis of PROP.

9.15.1 Blends

The first is blends formed from two other words like *smog*< ***sm****oke* + ***fog***, *brunch*< ***br****eakfast*+*l****unch*** or *spork* ***sp****oon* + ***fork***. One could imagine that this is done with the

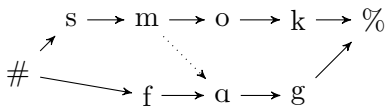
use of parallel streams for the two source words as in (120).

(120)



Maybe the above could be sufficient for the system to implement some sort of post-phonological 'convention' linearizing the above with the onset of one and the rest of the other. A common scenario is blends overlapping at their meeting point when they have some segments in common (Bat-El, 2006). Alternatively this could be made explicit with a vocabulary item adding an arrow.

(121)



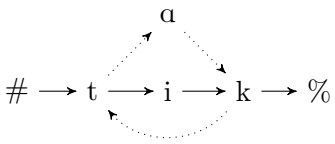
I am not convinced that a synchronic analysis of blends as word-formation is even necessary. The creation of new words is too open-ended to be reduced to a single word-formation module and *smog* may synchronically be simply its own vocabulary item in current I-languages. But occasionally some blends appear to be almost productive, like blends formed on the word *entertainment*, including *advertainment*, *infotainment*, *edutainment*, *wintertainment*, *politainment*, and *realitainment*. At some point it might be simpler to posit that a new root *-tainment* was abduced and that these forms are simple compounds, but the above would be a possible account if one were to argue for blends being productively created in a language through regular word-formation.

9.15.2 Ablaut Reduplication

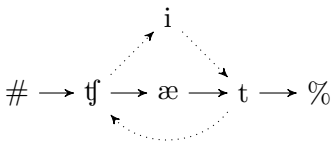
A second interesting but borderline pattern is English ablaut-reduplication in forms like *tick-tock*, *flip-flop*, *chit-chat*, *ding-dong*, etc. The reduplication part is straightforward to analyze in multiprecedence á la Raimy (2000), but the overall pattern of a front-high vowel

followed by a non-high back vowel is something multiprecedence has no way to enforce. In Multiprecedence a replacement vowel would be handled as fixed segmentism, with a vowel added that will surface in one of the copies. Note that the 'base' of those reduplicated forms, by which I mean the copy identical to the presumed unreduplicated word from which the reduplicated form is derived, is sometimes the first and sometimes the second, e.g. *tick-tock* < *tick*, but *chit-chat* < *chat*. Multiprecedence lacks a way to consistently enforce the high-and-front to non-high-and-back pattern to determine the order short of specifying a serialization order for each such form, which does not capture the pattern.

(122)



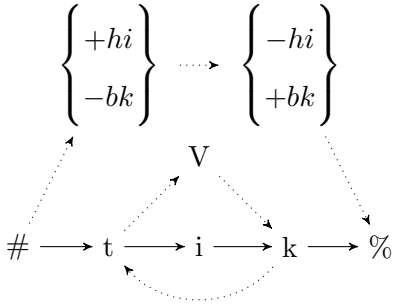
(123)



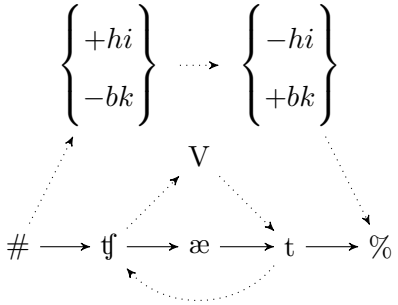
In contrast, the greater flexibility of PROP allows for the pattern to be specified on top of and separately from the reduplication. We can posit a forms like (124) and (125), where the fixed pattern is in parallel to the entire form and the reduplication, rather than posit a

specific vowel, posit an underspecified overwriting vowel.

(124)



(125)



Crucially, the two looped forms are indeterminate. The forms *tiktVk* and *tVktok* are equally good resolutions to the loop of (124), and similarly *ʧatʧVt* and *ʧVtʧat* for (125). But in both cases only one order 'fits' with the overarching melody. The /i/ of 'tick' is incompatible with $\{-hi, +bk\}$ and hence the derivation prefers *tik-tVk*, which puts the underspecified /V/ in parallel to $\{-hi, +bk\}$, making it surface as [ɑ], whereas the /æ/ of 'chat' is incompatible with $\{+hi, -bk\}$, hence the derivation prefers *ʧV-ʧat*, which puts the underspecified /V/ in parallel to $\{+hi, -bk\}$, making it surface as [i]. My suggestion is therefore an account in which indeterminate reduplicated forms can be settled on the basis of other facts about the form. This analysis thus captures the generality of the high-front to non-high-back pattern

Again, this analysis assumes that this ablaut reduplication is a synchronic and productive pattern of English, which I am not convinced of.

Chapter 10

Conclusion

The simple idea that we started from in this dissertation was what if we remove the stipulation that one segment has to follow or precede exactly one other, i.e. what if phonology did not operate on strings? This question was already posed by Raimy (2000) and the theory of Multiprecedence, who proposed that reduplication benefits from a representation capable of handling loops. The purpose of this dissertation was to expand on the logical possibilities of Multiprecedence when its representational freedom is harnessed to handle phenomena other than reduplication.

Let us review the phenomena which we have explored as potentially attributable to the representation with PROP.

In Chapter 3 we started from a simple and reasonable assumption: if two segments are parallel, i.e. have no specification as to whether one precedes the other, then they may be pronounced simultaneously up to phonetic compatibility. We saw that vowel harmony and word-tone phenomena could be handled by parallel streams in the representation. If a feature bundle can be set in parallel to another, and we posit that they can surface simultaneously, then we have all the complexity needed to create the phenomena in question.

In chapter 4 we discussed the possible role of parallel structures in handling the placement of affixes. If affixes can put in parallel to the stem they attach to, and restrictions of phonetic compatibility constrain the coordination of parallel segments, then we can utilize this to handle interesting phenomena of affixes with variable positions. But most affixes need to explicitly say where they are to be inserted so I also made use of the sticky-end technology to handle all types of affixation in a unified way.

Building on the two previous chapters, chapters 5 and 6 start from the observation that given multiprecedence technology, there is enough freedom in phonological representation to handle some amount of suppletion within a single underlying form. Again, rather than

an extra module dedicated only to this purpose, in PROP PCA arises entirely out of the freedom of the basic representation and the mechanics of the sticky-end. As a bonus, doing suppletion in the phonology has the advantage of creating a fully modular syntax prior to phonology that does not need to see phonological context prior to lexical insertion, and it resolves some puzzles in which phonology and allomorphy are intertwined.

Chapter 7 takes every innovation from the previous chapters and discusses their relationship with reduplication by discussing some examples with parallel structures. I hope to show in this chapter that PROP is truly a continuation of Multiprecedence capable of incorporating and expanding upon its insights with regard to reduplication as caused by loops in the representation.

Chapter 8 was a promissory excursion into acquisition and cognitive science. There we discussed how the handling of contradictory parallel features may boil down to general motor planning and perception of auditory events. We discussed how the parallel representation helps and redefines the learning problem of vowel harmony,

And finally chapter 9 was a grab bag of further issues that need to be addressed about PROP as a theory, and tentative proposals that possibly benefit from the addition of unspecified precedence in the theory.

Raimy's 2000 Multiprecedence made reduplication an integral phenomenon of word-formation arising from the raw combinatorics of the representation. This was a departure from all other existing theories in which there was a "core phonology" (Raimy, 2000, p.281) of linear concatenative phenomena, with something extra and, curcially, different tacked onto it to handle the non-core stuff. In Multiprecedence we see that reduplication is normal and fundamentally arises from the same ingredients as everything else. In Multiprecedence it would take extra stipulations to *not* have reduplication.

I hope that PROP can achieve the same for the other phenomena we have covered here. In just the same way that reduplication is often viewed as something extra tacked onto a concatenative phonology, the phenomena of vowel harmony and word-tone are often handled with extra structures, processes and constructs specifically designed to handle them. Even autosegmental phonology, for all non-linear that it is, is mostly treated as a string with extra stuff around it. PROP takes the non-concatenative word-level phenomena as core.

They follow from the representation in a deeply inextricable way, and we see that it would take extra stipulation to not have word-level phenomena of simultaneous morphology.

With PROP, a new picture of morphophonology can emerge in which reduplication, harmony, word-tone, and allomorphy do not feel like extraneous processes seemingly tacked onto a system that could exist without them. In PROP, the representation is simple and unrestricted, and all these 'exotic' non-linear, non-concatenative, and irregular phenomena exist not because they have entire pieces of machinery and modules of grammar dedicated to them, but because those things are simply what is possible when the representation is unrestricted and left to run free.

Removing the stipulation that phonology operates on strings explodes the range of possible configurations, and yet it turns out that all the main new geometric possibilities that this allows are attested in the world's languages. Lops were covered by Raimy (2000) as a way to handle reduplication. This dissertation mostly focuses on the phenomena that could be handled with segments that are unordered which I have referred to as being in parallel. From this I have proposed to derive multiple phenomena: when consisting of a few features in parallel to many segments I have proposed that this accounts for vowel harmony and word-tone. When branching within a single morpheme with separate sticky-end ends that can attach in different contexts I have proposed that this accounts for allomorphy. when affixation puts some affixes partially in parallel I have proposed that this may account for assimilation. When underlyingly parallel segments can be ordered in different ways based on context I have proposed that this accounts for metathesis. At least when looking at the simple new representational possibilities of PROP, it appears to me that this combinatoric richness matches the actual richness of morphophonological phenomena.

However there obviously are an infinitude of complex geometric structures that one could build from the powerful system described here and it is logically impossible for all of the geometric possibilities of directed graphs to be attested. But even short of infinitude it is clear that only a small number of geometric patterns have been discussed here and we may legitimately ask why, if PROP is correct, do we only see this small set of structures? It could be that as presented in this thesis is overly powerful, or it could be that external restrictions exist on attested phonological patterns. It is possible that Phonology is as

powerful as unrestricted PROP and the limitations in attested patterns is due to the limiting effects of acquisition and diachrony on what is likely to be attested in a real language. It is also possible that Phonology is intrinsically more powerful than phonetics/motor planning can handle, if for example some complicated graphs are perfectly computable within the phonology but too intricate to be interpretable downstream. This will, unfortunately, have to be the topic of further research.

Downing (2001), in her review of Raimy (2000), worried that the addition of loops and of a serialization algorithm capable of dealing with them only to account for reduplication was too heavy a cost for phonological theory. My response here is that there is much more that multiprecedence can be used for if we fully embrace its representational power.

There is a lot of work ahead for PROP. Everything here is very speculative. I hope to have been able to sketch the start of a program seeking to unify the myriad phenomena we covered here as straightforward manifestations of the combinatorics of the simple representation of PROP.

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