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The Representation of Vowel Height in Phonology

Dissertation

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Frederick Brooke Parkinson, B.A., M.A.

* * * * *

The Ohio State University
1996

Dissertation Committee:

David Odden, Adviser

Elizabeth V. Hume

Keith Johnson

Approved by

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Adviser
Department of Linguistics

to Elizabeth, my wife and best friend

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I am also indebted to Nick Clements and Sandy Schane, who have inspired me more than they know. I respect them and their work very much and enjoyed my all-too-brief opportunity to discuss my work with them. I would like to believe that what I present here builds on their work (perhaps contributing an incremental step), rather than departs from it. Despite any appearance to the contrary, I hold the greatest respect for the tremendous contributions made by these extraordinary phonologists.

In many ways, I owe my wife, Elizabeth Strand, the greatest thanks of all since it is she who has encouraged, assisted, cheered, fed, distracted, and tolerated me on a daily basis. She has helped me in every facet of my life, and done so in a way that proves I am the world's luckiest person.

In spite of the noble efforts of those mentioned (or omitted) above, some errors inevitably remain. Responsibility for these errors is mine alone.

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CHAPTER 1

1. Introduction

The aim of this dissertation is to propose a new means of describing vowel height, one that is consistent with the phonological patterning of languages as well as the phonetic facts. This proposal, the Incremental Constriction Model, characterizes vowel height in terms of multiple occurrences of the monovalent feature [closed], where each instance of this feature corresponds to a step along the height continuum. This dissertation develops this proposal demonstrating that it is an improvement over previous approaches to vowel height since the Incremental Constriction Model is able to account for all known height alternations without predicting unattested phenomena.

(1.1) The Incremental Constriction Model.

Height
|
[closed]
|
[closed]
|
[closed]

Vowel height is the phonetic and phonological parameter that distinguishes the sound [u] of 'boot' from the [o] of 'boat.' In a language that contrasts three vowel heights, two occurrences of [closed] are required to characterize its inventory. In such a language, the lowest vowels are specified for no height features, the mid vowels are specified for a single occurrence of [closed], and the high vowels are specified for two occurrences of [closed].

(1.2) Characterizing vowel height with [closed].

a. Three vowel heights.

	high	mid	low
[closed]	•	•	
[closed]	•		

b. Four vowel heights.

	high	hi-mid	lo-mid	low
[closed]	•	•	•	
[closed]	•	•		
[closed]	•			

Support for the Incremental Constriction Model over previous approaches to vowel height is found in partial height harmony. In partial height harmony, a vowel moves toward, but does not assume, the height of another vowel. In such an assimilation, the harmonizing vowel surfaces with a height between its original height and that of the vowel to which it assimilates. In an examination of all such assimilations, two previously undocumented generalizations emerge—all partial height harmonies involve a one-step change, and all partial height harmonies involve raising. These generalizations are true of all known cases of partial height assimilation, and hold true of all known cases of morphologically-induced raising. Yet, as robustly attested as these generalizations are, no previous approaches to vowel height are able to capture these generalizations by ruling out partial lowerings and two-step shifts.

The most dramatic examples of partial height assimilation are those in which vowels of different heights each undergo partial assimilation. Such cases of partial height harmony bear-out the generalizations mentioned above since all vowels that undergo the assimilation raise one step. An example of a partial height harmony in which more than one vowel assimilates is found in the Lena dialect of Spanish (Hualde 1989a, b). As will be discussed in detail in subsequent chapters, the vowel [a] raises to [e], the vowel [e] raises to [i], and the vowel [o] raises to [u] when followed by a suffix containing a high vowel. This one-step raising is seen in the examples *gat-a* versus *get-u* 'cat' and *bon-a* versus *bun-u* 'good' where the stem vowels are raised before the masculine plural suffix [u].

In the Incremental Constriction Model, these changes are described as an assimilation of the feature [closed] in which all non-high vowels acquire an occurrence of [closed]. The vowel [a] has no occurrences of [closed] underlyingly, but surfaces as [e] as a result of this assimilation; the vowels [e o] have one occurrence of [closed] underlyingly but surface as [i u] when acquiring a second instance of this feature.

(1.3)

a. a → e
e | [closed]

b. e → i
e | [closed] → i | [closed] | [closed]

c. o → u
o | [closed] → u | [closed] | [closed]

Partial height assimilations involving more than one height, such as Lena Spanish, pose a problem for approaches to vowel height that employ multiple features, e.g., [high] and [low]. In such a model, the change of $a \rightarrow e$ involves one feature ([low]) while the change of *e o* → *i u* involves a different feature ([high]), so that harmony like that of Lena defies a unified treatment. In the Incremental Constriction Model, however, all partial height harmonies are characterized as an assimilation for a single instance of [closed].

The Incremental Constriction Model builds on many previous approaches to vowel height, principally, Odden (1991), Clements (1991) and Schane (1984, 1990). In the following chapters, the Incremental Constriction Model is shown to be a substantial departure from the frameworks which inspire it, both in terms of the way in which vowel height is characterized and in the new insights it captures.

This dissertation comprises an examination of previous treatments of vowel height, an extensive survey of vowel height phenomena, an analysis of all known cases of partial height harmony, an account of vowel coalescence and diphthongization, and a case-study of height alternations in Kikuria. To accomplish this, several additional issues are addressed including what constitutes a "low" vowel, the distinction between complete and partial height harmony, the relationship between vowel place and vowel height features, an implementation of Optimality Theory (Prince and Smolensky 1993, McCarthy and Prince 1995), a formal account of featural assimilation in terms of "alignment" constraints, and a discussion of well-formed multiple associations.

This thesis achieves a number of results. A model of vowel height is articulated which characterizes vowel height contrasts in terms of multiple occurrences of the monovalent feature [closed]. *Consequence:* Vowel height is described in terms of a single phonetic scale.

The implementation of the Incremental Constriction Model is made explicit, and the predictions of this model enumerated. *Consequence:* The Incremental Constriction Model may be evaluated relative to previous models of vowel height.

Languages that contrast more than three vowel heights do not require the feature [ATR]. *Consequence:* Cross-height harmony is no longer predicted for all languages with more than three heights, but limited to just those languages in which [ATR] is active. In addition, languages with four or more heights, but without cross-height harmony can be described in a manner more consistent with the phonetics of these languages. That is, languages contrasting more than three heights no longer require [ATR] to "stand-in" (Clements 1991, Clements and Hume 1995). Instead, [ATR] is reserved for only those languages exhibiting the phenomena Stewart (1967) originally intended the feature to describe.

The number of heights that can be described is not limited by the set of features used to characterize the height continuum. *Consequence:* An elegant, straightforward analysis of vowel alternations in Sesotho, Setswana, and Northern Sotho (with five vowel heights) is possible.

Complete and partial height harmonies are formally distinguished. *Consequences:* The description of these harmonies is made precise in terms of the constituent sets of features for which a vowel assimilates in each phenomenon. Perhaps more importantly, the role of "contrast" may be carefully examined in each type of assimilation.

A number of partial height harmonies are identified, documented, and analyzed. *Consequences:* This survey allows this phenomenon to be studied, and establishes the importance of this phenomenon in the set of facts for which a model of vowel height must account.

Partial height harmony in which vowels of more than one height assimilate are accounted for. *Consequence:* The ad hoc formal devices otherwise invoked to handle languages exhibiting this phenomenon are no longer necessary. The simplicity of the account for this phenomenon is consistent with the number of languages that display it.

A generalization is identified among partial height harmonies: all such assimilations involve raising vowels one step. *Consequence:* This generalization points to a fact that distinctive feature theory should predict. This generalization is important both because it has never been documented before, and because it establishes the inadequacies of all previous approaches to vowel height. In addition, it provides a new area for phonetic research.

A number of non-assimilatory height shifts are identified and documented. *Consequence:* This survey of languages enables the *raising* generalization to be extended to this phenomenon as well.

The necessity for characterizing vowel inventories on the basis of the system of contrasts and alternations found in a given language is established. *Consequence:* The characterization of vowel systems is more illuminating. Languages may vary with respect to the phonological structure they assign to even similar phonetic spaces. The description of vowel space is no longer based on a-priori considerations of inventory.

This dissertation is organized as follows: Chapter 1 provides an overview of the study itself. Chapter 2 introduces the Incremental Constriction Model, and defines its properties and explains their consequences. Among the properties discussed are the incrementality and monovalency of the feature [closed], as well as the fact that the Incremental Constriction Model characterizes vowel height exclusively in terms of "increased height." These properties make the Incremental Constriction Model a substantial departure from previous approaches to vowel height. In this chapter, the Lena dialect of Spanish is examined, and the Incremental Constriction Model is implemented to account for partial height harmony in this language.

Chapter 3 presents a wide range of languages, all of which exhibit one-step raising, many assimilatory and some morphologically conditioned. The phenomenon of one-step raising provides substantial support for the Incremental Constriction Model since this model uniquely captures the generalization that all such shifts are one-degree changes which raise vowels. The discussion in this chapter is framed within the constraint-based approach, Optimality Theory. Height assimilation, in this framework, is described in terms of alignment constraints that require an occurrence of the feature [closed] to be aligned to two edges of a domain. While numerous geographically and genetically diverse languages are discussed, the formulation of the alignment constraints required to account for these cases vary only with respect to three parameters, whether the triggering vowel can be of any height or must be a high vowel, the morphological affiliation of the triggering vowel, and whether alignment is leftward or rightward.

Chapter 4 is an investigation of other height-related issues including, complete height harmony, coalescence, diphthongization, what constitutes a "low" vowel, and the relationship between vowel place and height features.

Chapter 5 is a case-study of Kikuria, a Bantu language that exhibits a wide range of height-related alternations including partial and complete height harmony, and coalescence. An extended analysis of one language exhibiting this range of height alternations exemplifies how constraint-based phonology in general, as well as the Incremental Constriction Model in particular, account for multiple, related phenomena.

Chapter 6 summarizes the results of the previous chapters.

Chapter 2

THE INCREMENTAL CONSTRICTION MODEL

2.0 Introduction

This chapter introduces the approach to vowel height proposed in this thesis, the Incremental Constriction Model. Here, a number of background issues are discussed which form the foundation upon which subsequent discussion is based. The notion of distinctive features is introduced, and the aims of distinctive feature theory are presented. The issue of feature constituents is outlined, and arguments supporting the recognition of three key constituents are reproduced, following the authors who initially proposed them. The properties of the Incremental Constriction Model are briefly introduced, as are the implications of these properties. Finally, the predictions of the Incremental Constriction Model are enumerated.

Phonology is the study of the systematic patterns in the pronunciation of speech, which seeks to develop a model to account for the patterns of sounds found in all human languages while ruling out sound systems not found in any language. Phonological theory describes speech sounds in terms of a small set of distinctive features, which are the individual phonetic parameters that define these sounds. For example, the English sound [s] differs from [z] in terms of the distinctive feature [voice], where [s] is not characterized by this feature but [z] is characterized by [voice], indicating that the vocal folds vibrate during the production of [z].

A major shortcoming in our understanding of how speech sounds are described is the lack of an adequate theory of vowel height, the phonetic parameter by which [i] (the vowel in 'beet') differs from [e] ('bait'), and [u] ('boot') differs from [o] ('boat'). The vowels [i] and [u] are the highest vowels along the vowel height continuum, and are produced with a relatively higher tongue body than are [e o]. This dissertation proposes a new model of vowel height which better characterizes what types of alternations are found in the world's languages, and what types should never be found.

The major empirical goal of phonological theory is predicting possible phonological alternations, which are variations in the phonetic realization of a given sound as determined by the sounds around it. For example, the phonetic realization of the plural *-s* varies as a function of the last sound of the noun to which it attaches, as seen in the words *cat*[s] where it is [–voice] and *dog*[z] where it is [+voice]. In this case the plural *-s* assimilates to the [voice] specification of the sound it follows. This is formalized as spreading the feature [voice] from the final consonant of the stem to the consonant of the plural *s*. Since alternations are described in terms of distinctive features, an adequate model of the features

that characterizes vowel height should predict the kinds of vowel height alternations that are attested cross-linguistically.

All previous attempts to delineate a set of features to characterize vowel height have failed in at least one of two ways. Most previous accounts are unable to characterize the full range of height alternations found in the world's languages, and no previous model captures a generalization that holds of a class of height alternations: namely, that all partial height harmonies raise their targets one step. The height assimilation found in the Lena dialect of Spanish mentioned above (and discussed in detail in §2.3) illustrates these points. Recall that a high vowel triggers the raising of /a/ to [e], of /e/ to [i], and of /o/ to [u]. If vowel height is described in terms of multiple features, e.g., [high] and [low], then Lena height harmony defies a unified account since the raising of /a/ → [e] is characterized in terms of one feature ([+low] → [–low]) and the raising of /e o/ → [i u] is characterized in terms of another feature ([–high] → [+high]). Below, the Incremental Constriction Model is shown to account for Lena and other height harmonies in terms of a single height feature, [closed]. In addition, Lena height harmony exemplifies the generalization alluded to above: all height harmonies in which a vowel assimilates to the height of another vowel but does not attain the height of that vowel (i.e., partial height assimilation) involve raising. No vowel partially lowers in assimilation to the height of a lower vowel. Since height is characterized in terms of the monovalent feature [closed] in the Incremental Constriction Model, all assimilations defined in terms of a single height feature (i.e., partial height harmony) will result in raising a vowel one step. Models that include the features [–high], [+open], or an element that corresponds to "lowered height," incorrectly predict partial lowerings.

2.1 Properties of the Model

The Incremental Constriction Model is a theory of the representation of vowel height that captures a number of cross-linguistic generalizations concerning vowel height phenomena. In this approach, vowel height is modeled as in (2.1), where vowel height is characterized by multiple occurrences[1] of the monovalent feature [closed].

(2.1) The Incremental Constriction Model of vowel height.

Vocalic
Height
[closed]
[closed]
[closed]

This section examines the properties of the Incremental Constriction Model, including the definition of [closed], incrementality, monovalency, and the fact that vowel height is characterized here exclusively in terms of increased height.

[1] While three occurrences of [closed] are depicted in (2.1), the number employed by a given language is determined by the number of heights in that language, where some languages require more or fewer occurrences of this feature to characterize their inventories.

2.1.1 Defining [closed]

Many authors have argued that articulatory definitions of (phonological) vowel height are problematic since such descriptions of vowel height are inconsistent with the production of vowel height (Ladefoged 1964, Lindau 1975). These authors prefer acoustic definitions (Ladefoged 1964, Heffner 1964, Lindau 1975, and others but see, for example, Lindblom and Sundberg 1969). Vowel height is argued to be best described in terms of a vowel's first formant frequency (F1), where low vowels have a relatively higher F1 while high vowels have a lower F1 (Ladefoged 1971:67-74, among others, see especially Lindau 1975, Traunmüller 1981). In the Incremental Constriction Model, a vowel specified for more occurrences of [closed] than another vowel also has a lower F1 than that vowel (all else being equal).

Occurrences of [closed] correspond to increased constriction in the vocal tract during the production of vowels, and thereby increased vowel height. The feature [closed], therefore, is defined in terms of decreased F1. In order to correct for the different F1s of front and back vowels, height is often defined in relation to the second formant frequency (F2), e.g., F2–F1 (e.g., Lindau 1975). To normalize across speakers, height is sometimes characterized in relation to fundamental frequency (F0), e.g., F1–F0 (e.g., Taunmüller 1981, Di Benedetto 1994). Because vowel space in general, and especially vowel height, is continual in nature (Abercrombie 1967), languages with even the same number of distinctions along the continuum do not necessarily make the distinctions at the same point (Heffner 1964; Disner 1978, 1983). Disner (1978), for example, examined six Germanic languages (Danish, Dutch, English, German, Norwegian, and Swedish) and found that what is transcribed as the same vowel across these languages varied in acoustic properties. The acoustic spaces of vowel [e] in English and Dutch, for example, do not overlap. Thus, it is impossible to define the exact F1 frequency at which a low vowel becomes non-low (and thereby acquires its first occurrence of [closed]). It is more important to identify the correct continuum than to demarcate the sharp boundries along that continuum.[2] Vowel height constitutes a single phonetic dimension. The "steps" along that dimension are language-specific.

2.1.2 Incremental Features

The Incremental Constriction Model recognizes vowel height as a single phonetic scale, along which languages may distinguish some number of contrasts. Each contrast along this scale is characterized by an occurrence of the monovalent feature [closed]. The feature [closed] is *incremental* since more than one instance of this feature may specify a single vowel. Incremental features have been proposed previously for vowel height, notably in Schane (1984, 1990) and Clements (1989, 1991). Both of these authors found incremental (or scalar) features to be better suited to vowel height than a set of disparate features that characterizes orthogonal dimensions in the vowels space (see also Hayes 1990). As will be discussed below, the differences between the Incremental Constriction Model and the proposals of these authors result in a theory that better predicts the types of assimilations found in the world's languages.

Trubetzkoy (1939) distinguishes three types of oppositions, privative, gradual, and equipollent. It is argued here that vowel height contrasts are gradual oppositions since vowels of different heights "are characterized by various degrees of gradations of the same property" (Trubetzkoy 1939:75)[3]. The various degrees of vowel height within a language

[2] I thank Donca Steriade for reminding me of this point.

[3] Trubetzkoy (1939:77) observes that height contrasts may be gradual or privative depending "on the

are characterized by multiple occurrences of the feature [closed]. The incrementality of the feature [closed] captures the gradual nature of vowel height contrasts. In Lena, for example, the vowel [a] raises one increment to [e], the vowel [e] raises one increment to [i], and the vowel [o] raises one increment to [u], demonstrating that vowel height is incremental, or gradual.

Characterizing vowel height in terms of incremental features also captures the fact that partial vowel height assimilations involve single-increment steps along the height continuum. Traditional nonlinear phonology assumes that assimilation is described in terms of sharing either all the features of a particular constituent, or a single feature. In a partial height assimilation, therefore, a single height feature is shared. In the Incremental Constriction Model, a partial height assimilation involves a single instance of [closed], which corresponds to a single step or increment along the height continuum. The difference between this approach and that of Clements (1989, 1991) is discussed below.

The number of instances of [closed] active in a language is determined by the number of vowel heights in that language. Low vowels are universally specified for no occurrences of [closed], i.e., they possess a bare Height node. The lowest non-low vowels in a language are specified for a single occurrence of [closed]. Each successively higher vowel is specified for an additional occurrence of this feature. The highest vowels in a language are always specified for the greatest number of occurrences of [closed] of any vowel in the system. The highest vowels, then, are said to be specified for $[\text{closed}]_{max}$, the notation for maximum instances of [closed].

Languages may refer to the highest vowels in their inventories. For example, in some languages, only the highest vowels trigger partial height harmony (e.g., Servigliano Italian, Basque, and Kikuria, all discussed in Chapter 3). In these languages, the triggers of harmony have a special status, $[\text{closed}]_{max}$. The highest height is the only height to which a language may refer directly. That is, a language may refer to $[\text{closed}]_{max}$, but not to $[\text{closed}]_{max-1}$.

Languages do not need to count to determine how many instances of [closed] constitute $[\text{closed}]_{max}$. Instead, a language has access to its complete inventory, and through comparison, determines which vowels are specified for more occurrences of [closed] than all others. To these vowels, e.g., [i u], the language assigns $[\text{closed}]_{max}$ status. The output of assimilation or other processes may then be compared to [i u] to determine whether that output is specified for an equal number of occurrence of [closed] as are the $[\text{closed}]_{max}$ vowels.

2.1.3 Monovalent Features

The feature [closed] is *monovalent*, meaning that languages may only insert, spread, or delink the presence of this feature. In contrast, binary models posit that each feature in the system has two values: positive [+] and negative [–], such that both values are expected to spread, delink, etc., cross-linguistically. It has been argued that reference to both values of at least certain features is unnecessary, and that where possible, only one value of a feature should be recognized. Authors have posited that other features are monovalent. The feature [labial], for example, is widely accepted as monovalent since the phonology of no language makes reference to the negative value, [–labial] (Selkirk 1993 and references therein). Characterizing vowel height contrasts in terms of monovalent elements has been

structure and functioning of the respective phonemic system." While not all languages contrast enough heights to attain the status of 'gradual opposition,' there are a large number of languages that do contrast sufficient phonemic heights to warrant the 'gradual' label.

argued for by many authors, including Schane (1984), Anderson and Ewen (1987), Kaye et. al. (1985), Selkirk (1991), and Goad (1993).

In recent literature, the terms 'monovalent' and 'privative' are often used interchangeably. Trubetzkoy used the term 'privative' to characterize the class of *oppositions* which are described by the presence or absence of a characteristic (which could be characterized by the [+] and [–] value of a binary feature). To avoid confusion, the term monovalent is used here to describe the *feature* [closed].

2.1.4 Features Corresponding to Increased Constrictions

The Incremental Constriction Model characterizes vowel height exclusively in terms of increased constriction with [closed]. This is in contrast to models that characterize vowel height with features that make reference to raised and lowered tongue body (or increased and decreased constriction), e.g., [high] and [low] (Chomsky and Halle 1968, Sagey 1986, Wiswall 1991), [dorsal] and [pharyngeal] (Selkirk 1991), and [±open] (Clements 1989). Other models characterize vowel height solely in terms of a lowered tongue body (or decreased constriction), e.g., the particle *a* (Schane 1984, Kaye et. al. 1985, Anderson and Ewen 1987) as well as [open] and [low] (Goad 1993). Within the Incremental Constriction Model, vowel height is characterized exclusively with the feature [closed]. Low vowels are specified for no occurrences[4] of [closed]. A specification for [closed] indicates that a vowel is non-low, and each subsequent occurrence of this feature corresponds to the next "higher" step along the vowel height scale. Only the Incremental Constriction Model describes vowel height soley as increased constriction.

Since [closed] is monovalent, the phonology only has access to the presence of [closed]. Approaches that employ features that correspond to both increased and decreased constriction allow the phonology access to both of these dimensions. The approaches in which all height features correspond to decreased constriction allow access only to this dimension. These differences make very different predictions with respect to assimilations involving single features. These differences are illustrated in §2.2.

2.1.5 Organization of [closed]

Occurrences of [closed] are organized beneath the Height node. The first occurrence of [closed] is linked directly to the Height node, and each subsequent occurrence of [closed] is linked directly to the previous instance of that feature. The result is that occurrences of [closed] are "stacked" as in (2.2). If a language contrasts just two heights, then high vowels have the structure in (2.2.a). In a language that contrasts four vowel heights, high vowels have the stucture in (2.2.b). The degree of constriction is correlated with the number of occurrences of [closed] that characterize a given vowel. However, the tier on which an occurrence of [closed] resides plays no role in the phonology. Each occurrence of [closed] is indistinguishable from all others so that it is not possible to derive a phonological distinction between a vowel specified for one occurrence of [closed] and another vowel also specified for a single occurrence of [closed] where that feature resides on a different tier.

[4] While low vowels do have a constriction, they are specified for no occurrences of [closed], corresponding to the fact that they are the "low" extreme of the height continuum.

(2.2) Occurrences of [closed] are "stacked."

a.
Height
|
[closed]

b.
Height
|
[closed]
|
[closed]
|
[closed]

This arrangement of the incremental feature [closed] predicts that single feature assimilation may only precede from a Height node with more occurrences of [closed] to a vowel specified for relatively fewer occurrences of the feature. This means that only higher vowels may trigger partial height assimilation in lower vowels. This follows from well-established notions in phonology.

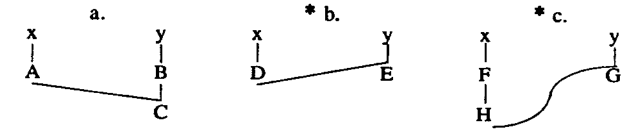
Two standard assumptions in non-linear phonology are that elements on a single tier are ordered, i.e., they exist in a precedence relation (Sagey 1990, Kornai 1995:7), and that elements connected by an association line are in a dominance relation. Following Partee et. al. (1990:442),[5] and Hume (1994:152) these relations are understood to be exclusive such that no two elements may exist in both relationships with each other.

(2.3) Dominance/Precedence prohibition.

If two elements are in a dominance relation, then those elements are not in a precedence relation. If two elements are in a precedence relation, then they are not in a dominance relation.

The structure in (2.4.a) is well-formed since it does not violate (2.3). The structures in (2.4.b, c) violate (2.3). In (2.4.b), *D* precedes *E*, since they are on the same tier. Further, *D* is shown to dominate *E*, so that these two elements are in both a dominance and precedence relation as is prohibited by (2.3). Simiarly, the element *F* in (2.4.c) dominates *H* and *H* is shown to dominate *G*. Since dominance is transitive, *F* and *G* are also in a dominance relation, so that this structure is ruled out by (2.3).

(2.4) a. *b. *c.



ε → e / _ i ε → e / _ ε e → i / _ ε

As the structures in (2.4.b, c) violate (2.3), they are universally prohibited and, therefore, unattested in the world's languages. High vowels, which are specified with the maximum number of occurrences of [closed] in any given language, are frequent triggers of partial height harmony. This is argued to be a result of the fact that as the highest

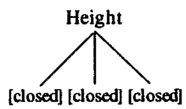
[5] Chris Barker (pc) points out that the Exclusivity Condition, as stated in Partee et. al., predicts that any two elements must be in either the dominance relation or the precedence relation. As such, the Exclusivity Condition does not hold for the phonological representation under discussion here. The statement in (2.3), though similar to the Exclusivity Condition, allows two elements to be in neither relation.

vowels, they may spread [closed] to any non-high vowel in the language. In contrast, the vowel [a], universally specified for no occurrences of [closed], never triggers partial height harmony, as predicted by the Incremental Constriction Model since this vowel has no instance of [closed] to spread.

The Dominance/Precedence prohibition (2.3) captures an important generalization among partial height harmonies: namely, only higher vowels may trigger a single-feature assimilation in lower vowels. This result is achieved through an appeal to independently motivated notions including dominance, precedence, and exclusivity (Partee et. al. 1990).

Capturing the "only higher vowels trigger" generalization cannot receive a straightforward treatment if instances of [closed] are arranged in the alternative organization in (2.5).

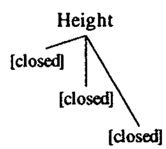
(2.5) Flat structure organizing [closed].



In order for the flat organization in (2.5) to capture the "only higher vowels trigger" generalization, the phonology would need to count instances of [closed] to determine which of two Height nodes dominates the greater number of instances of [closed]. Counting occurrences of [closed] would be necessary for the phonology to determine whether the structure violates a principle that requires triggers to have a larger number of occurrences of [closed], and thus, are higher. Because this alternative requires counting, it is dispreferred.

A cascading organization is assumed by Clements (1991), where each height feature occupies its own tier, and is linked directly to the Height node.[6] The cascading structure in (2.6) is not incompatable with a treatment of the "only high vowels trigger" generalization based on the Dominance/Precedence prohibition.

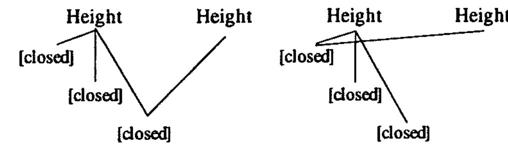
(2.6) Cascading structure.



While the cascading structure captures the "only high vowels trigger" generalization without resorting to counting, this organization is dispreferred for another reason. In (2.6), each occurrence of [closed] is its own autosegmental element. This cascading structure allows any occurrence of [closed] to spread independently of the others so that either of the spreadings in (2.7) are possible.

[6] Clements (1991) characterizes height with degrees of the feature [±open] which are organized beneath an Aperture node.

(2.7) Two formulations of a single-feature assimilation.



As multiple formulations of partial height harmony are possible, several phonologically distinct outcomes are expected to arise from spreading a single instance of [closed], depending upon "which" instance of [closed] is spread (Clements 1991). In the organization in (2.6), the tier on which a feature resides has phonological significance. This is in contrast to the organization in (2.2) in which each occurrence of [closed] is indistinguishable from the next. Thus, the structure in (2.2) allows only one formulation (and thus, one interpretation) of any single-feature assimilation.

The examination of partial height harmony that follows in Chapter 3 reveals that the additional power obtained in (2.6) is not necessary. No language crucially makes reference to the specific tier on which an occurrence of [closed] resides. All single-feature height assimilations have the same phonological consequence: all such assimilations raise their targets one step.

Instances of [closed] are organized as in (2.2) since this structure exhibits the crucial properties required of the model. The Incremental Constriction Model places no importance on the tier on which an occurrence of [closed] resides since no such reference is necessary. In addition, the organization in (2.2) captures the generalization that only higher vowels trigger partial height harmony through appeal to the independently motivated properties of dominance and precedence.

2.2 Predictions of the Model

The Incremental Constriction Model characterizes vowel height exclusively in terms of a monovalent feature corresponding to increased constriction. As stated above, this predicts that any single feature[7] height assimilation necessarily involves raising. Moreover, because each occurrence of [closed] characterizes one increment in the height continuum, the Incremental Constriction Model predicts that all partial height assimilations move their vowels one step along this scale.

(2.8) Predictions of the Incremental Constriction Model.
   a. All partial height harmonies involve a one-step change.
   b. All partial height harmonies involve raising.

In contrast, a model of vowel height that includes features (or elements) that correspond to lowered height predicts that partial lowerings should be found among the world's languages. That is, a model that includes the feature [–high] (e.g., Sagey 1986, Wiswall 1991) suggests that some language should exhibit an assimilation for just that one feature.

[7] See Clements (1985) for discussion of single-feature versus multiple feature assimilations. Below (see Tableau 3.4 in §3.1.1), the interaction of constraints limits the spreading of height features in the Incremental Constriction Model to either one occurrence of [closed] or every occurrence of [closed].

Spreading [–high] to a non-high vowel has no effect. But spreading this feature to a high vowel will lower that vowel.

An extensive survey of partial height harmony (presented in the Chapter 3) reveals that the predictions of the Incremental Constriction Model, (2.8), are correct. All partial height harmonies are one-step raisings. Since only the Incremental Constriction Model characterizes vowel height exclusively in terms of increased constriction, only this model captures the "one-step raising" generalization (borne out by the languages discussed in Chapter 3).

2.3 Lena Spanish

The Lena dialect of Spanish (Hualde 1989a, b; Kaze 1989; Dyck 1995; Parkinson 1995a, 1996a; Martínez-Gil 1996; and §3.1.1 below) is spoken in Asturias containing the vowels [i e a o u]. Lena vowels are specified within the Incremental Constriction Model in (2.9).

(2.9) Vowels of Lena Spanish.

	i	u	e	o	a
[coronal]	•		•		
[dorsal]		•		•	
[closed]	•	•	•	•	
[closed]	•	•			

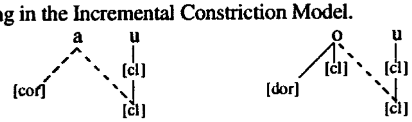
Lena Spanish, like many dialects in the Romance family, exhibits metaphony effects, i.e., stem vowel alternations triggered by a suffix containing the high vowel [u]. Lena metaphony raises the stressed vowel one step, as shown in (2.10).

(2.10) Metaphony effects in Lena Spanish.

	mas. sg.	*fem. sg.*	*gloss*
a → e	gétu	gáta	'cat'
	séntu	sánta	'saint'
e → i	nínu	néna	'child'
	bwínu	bwéna	'good'
o → u	kúšu	kóša	'cripple'
	búnu	bóna	'good'

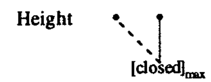
Based on the specifications in (2.9), the changes in (2.10) are described as an increase in the number of occurrences of [closed] for each stressed vowel. The vowel [e] is specified for one occurrence of [closed] and raises to [i] when it acquires an additional instance of this feature. Likewise, [o], with one specification for [closed], surfaces as [u], with two occurrences of [closed]. The vowel [a], which is specified for no features, surfaces as a mid vowel when it acquires an occurrence of [closed], and surfaces with the default place, [coronal] (Hume 1994, 1996).

(2.11) One-step raising in the Incremental Constriction Model.



In non-linear phonology, Lena metaphony, as depicted in (2.11), can be described as an assimilation of the feature [closed]. The alternations in (2.10) are a partial height harmony since the assimilating vowel does not assimilate to the place of the trigger (*e* → *i* before *u*), nor does it necessarily emerge with the same height as the trigger (*a* → *e* before *u*). Following Clements (1985), partial height harmony is expressed as a single-feature assimilation involving a vowel height feature. Following Goldsmith (1979), Clements (1985), Hayes (1986), Sagey (1986) and others, assimilation is formalized as sharing structure. The structure shared between trigger and target in (2.11) is an instance of the feature [closed].

(2.12) Lena Metaphony—formalized as spreading.



The trigger of Metaphony is a high vowel, i.e., a vowel specified for the maximum number of occurrences of [closed] in the language, which is denoted as $[\text{closed}]_{max}$ in (2.12). Notice that both sets of changes, [a] to [e] as well as [e] to [i] and [o] to [u], are characterized identically, in terms of [closed]. If the vowels in Lena were characterized in terms of [high] and [low], then each of these changes would involve a different feature.

(2.13)	a → e	[+low] → [–low]
	e o → i u	[–high] → [+high]

Lena Spanish illustrates, then, the problem that partial height harmony poses for the description of vowel height: vowel height must be characterized in terms of a phonetic continuum since vowels shift one step along this scale. In approaches that characterize the continuum with disparate features, no unified description of step-wise phenomena is possible.

Lena also illustrates another problem for the representation of vowel height in that it exemplifies two generalizations that should be captured by an approach to vowel height. First, each vowel that undergoes Lena Metaphony undergoes a one-step change. This is true in all languages exhibiting partial height harmony (Parkinson 1994). No language displays a two-step change in height (e.g., no language in which [e] and [ɛ] contrast for height raises /ɛ/ to [ɪ] before [i]). In addition, Metaphony raises vowels in Lena, as all other cases of partial height assimilation also involve raising. No language partially lowers a vowel. These generalizations are captured in the Incremental Constriction Model since [closed] corresponds to increased height and denotes one increment along the height continuum. All assimilations for this one feature, then, necessarily involve a one-step raising change (cf. §2.2).

2.4 Constituents

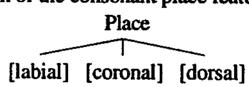
Any theory of distinctive features must address the issue of feature constituents. A group of features is said to form a constituent if they pattern together cross-linguistically. Mascaró (1983), for example, argues that the features that characterize the place of articulation for consonants form such a constituent. He notes that nasal consonants assimilate to the place of a following consonant, as seen in (2.14). Since the nasal assimilates for all place[8] features, Mascaró argues that this assimilation must be defined in terms of a set of constituent features—the *place* constituent.

(2.14) Catalan nasal place assimilation.

kín əmík	'which friend'
kín̪ día	'which day'
kíɲ λúm	'which light'
kíɲ ɲaɲu	'which bump'
kíŋ káp	'which head'
kím més	'which month'

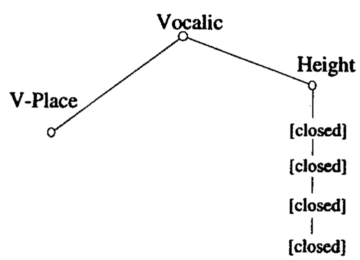
Mascaró (1983), Clements (1985 and elsewhere), Sagey (1986, 1990) and others represent feature constituents hierarchically, as in (2.15). In such models, an assimilation for a single feature is formalized by spreading that feature, while the assimilation in (2.14) is formalized by spreading the entire Place node.

(2.15) Hierarchical organization of the consonant place feature constituent.



The Incremental Constriction Model (2.16) recognizes three constituents among vowel features, the set of all vowel features (the Vocalic constituent), the set of vowel place, or color features (the V-Place constituent), and the set of vowel height features (the Height constituent). Each of these constituents corresponds to an organizing, or class node, in the hierarchical representation in (2.16) following Clements (1985), Sagey (1990), and others.

(2.16) The Incremental Constriction Model.



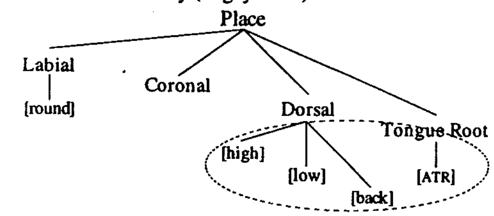
These constituents are recognized in order to account for multiple feature assimilations found among the world's languages (Clements 1989, 1991; Clements and Hume 1995; Odden 1991; Wiswall 1991). Not all authors recognize exactly these three constituents among vowel features (see Sagey 1990, Halle 1995, Goad 1993 among others for different approaches). The sections below outline the evidence supporting the constituents depicted

[8]Mascaró refers to the set of place features as "point of articulation" features.

in (2.16). For a more comprehensive comparison of various approaches to vowel features, see Odden (1991), Clements (1989), Wiswall (1991), and Clements and Hume (1995).

While many of the differences among the various proposals for the organization of features are orthogonal to the current discussion, one issue will be examined, namely that concerning the separation of vowel place and vowel height features. In many models, vowel features are dominated by several nodes, but no distinction is formally recognized between place and height. In (2.17, from Sagey 1990), vowels are characterized by the features [round], [back], [high], [low], and [ATR]. The only node dominating all of these features is Place, a node dominating the consonantal place features Labial, Coronal, Dorsal, and Tongue Root as well.

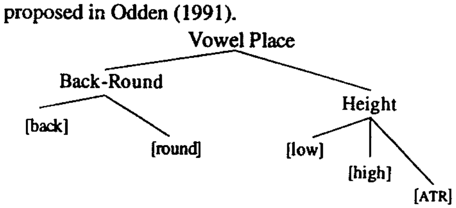
(2.17) The Articulator Node Hierarchy (Sagey 1990).



Models like the one in (2.17) have been criticized for their inability to characterize certain types of assimilations (Clements 1989, Odden 1991, Selkirk 1991, Wiswall 1991). For example, an assimilation in which a vowel assimilates to the backness and roundness of another vowel cannot be described, assuming the model in (2.17), since the features characterizing these qualities cannot be spread to the exclusion of other features. That is, [round] and [back] cannot spread independently of [high] and [low]. Thus, (2.17) predicts that any assimilation involving [round] and [back] necessarily involves [high], [low], and [ATR] as well.

Later models of feature organization structurally distinguish between height and place features by separating the two groups of features so that each set is dominated by a distinct node (Clements 1989, Odden 1991, Wiswall 1991, Goad 1993, and others). Odden (1991) proposes the model in (2.18), which predicts that the features [back] and [round] may spread together to the exclusion of [high] and [low] since in this model, the node Back-Round dominates the former, but not the latter.

(2.18) Geometry proposed in Odden (1991).



For the purposes of this dissertation, vowel height features are defined as those features dominated by a Height node.[9] The distinction between height and place features is meaningless in models like that shown in (2.17) where organizing nodes do not differentiate between these groups of features.

2.4.1 The Vocalic constituent

The Vocalic constituent is recognized to account for assimilations in which a vowel harmonizes for all features with another vowel. Such assimilations are found in Efik (Parkinson 1993b), Kashaya (Buckley 1993), Klamath (Barker 1964), Loniu (Hamel 1985), Djingili (van der Hulst and Smith 1985), Tibetan (Dawson 1980), Walpiri (van der Hulst and Smith 1985), Nyangumarta (Hoard and O'Grady 1976), and Hottentot (Hagman 1977).

In Efik (Parkinson 1993b), a Benue-Congo language spoken in Nigeria, total vowel harmony applies to the negative marker /-kɛ/. In this harmony, /-kɛ/ harmonizes completely to the quality of the root vowel when it is suffixed to a monosyllabic, vowel final stem. In the examples in (2.19.a), the negative marker surfaces as *-kɛ* because it is added to a root containing two syllables or a coda consonant. In (2.19.b), the negative marker *-kɛ* assimilates completely to the quality of the verb root.[10]

(2.19) Efik harmony in suffixes.

a.	ŋ́-bára kɛ́	'I am not burning'
	ŋ́-kɔ́ŋ kɛ́	'I am not coughing'
	ŋ́-kót kɛ́	'I am not reading'
	ń-núk kɛ́	'I am not pushing'
	ń-tɨ́ŋ kɛ́	'I am not saying'
b.	ŋ́-kpá-čá	'I am not dying'
	ŋ́-kɔ̌-čɔ́	'I am not fishing'
	ń-tó-čó	'I am not coming from'
	ḿ-bú-čú	'I am not rotting'
	ŋ́-kpɨ́-čí	'I am not slashing'

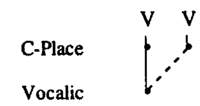
Comparing examples like *ŋ́-kpá-čá* in (2.19.b) to forms like *ḿ-bárá-kɛ́* 'I am not burning (transitive)' and *ń-tɛm-kɛ̌* 'I am not cooking' show that Total Harmony in Efik is sensitive to foot structure (cf. Akinlabi and Urua 1993, and Hyman 1990) so that it applies only when the negative suffix can be incorporated into the stem foot (i.e., when suffixed to a monosyllabic, vowel final root.)

The examples in (2.19) demonstrate that the suffix vowel assimilates for all vowel features since both the height and place of the harmonizing vowel are completely predictable from that of the preceding root vowel. Total vowel harmony in Efik involves spreading the Vocalic node (Parkinson 1993, assuming the organization in Clements and Hume 1995).

[9]See Selkirk (1991) for another means of implementing this distinction.

[10] The vowel /i/ surfaces as [ɨ] due to an independent process (see Parkinson 1993b). Thus, /ń-kpɨ́-kɛ́/ → *ŋ́-kpɨ́-čí* 'I am not slashing.'

(2.20) Total vowel harmony in Efik.



Formalizing total harmony in Efik as an assimilation of the Vocalic node (2.1) expresses the generalization that this harmony involves all vowel features. No straightforward account of the Efik facts is possible without recognizing the Vocalic constituent.

2.4.2 The V-Place Constituent

The V-Place constituent is recognized in order to account for assimilations in which a vowel assimilates to at least two place features, but not the height, of another vowel. Place harmony is found in Cheremis (Odden 1991), Efik (Parkinson 1993b), Ngbaka (Thomas 1963, Steriade 1987, Parkinson 1995c, and elsewhere), Wikchamni (Archangeli 1985), Macushi (Odden 1991), Maxakali (Clements 1989), Feʔfeʔ Bamilike (Hyman 1972), and Ewe (Clements 1974).

Cheremis (Odden 1991), a Uralic language, has the vowel inventory in (2.21). Backness and roundness are distinctive in Cheremis since roundness cannot be predicted from backness, nor vice versa. Cheremis exhibits a process of harmony whereby non-low vowels assimilate to the backness and roundness of a preceding vowel.

(2.21) Cheremis vowels.

i	ü		u
e	ö	ə	o
		a	

In the examples in (2.22), the possessive suffix assimilates to the backness and roundness of the root vowel. While the suffix always surfaces with a mid vowel, it surfaces as /še/ after front unrounded vowels, as /šö/ after front rounded vowels, and as /šo/ after back vowels. The examples in (2.22.c) show that when the last root vowel is [ə], the suffix harmonizes with the penultimate root vowel. When all root vowels are [ə] as in *əštə-* 'make,' the suffix surfaces as [e].

(2.22) Cheremis place harmony.

a.	kit-še	'his hand'
	boz-šo	'his wagon'
	surt-šo	'his house'
	šör-žö	'it's milk'
	üp-šö	'his hair'
b.	pur-mo	'entering'
	əštə-me	'made'
	šogə-mo	'standing'
c.	ergə-že	'his boy'
	surtəškə-žo	'to his house'
	pörtəštə-žö	'in his house'

Odden argues that Cheremis harmony is best formalized as spreading the vowel place node from the root to non-low suffix vowels, as in (2.22). Since the features characterizing backness and roundness are dominated by V-Place, such a formalization correctly predicts that harmonizing suffixes will agree for these features with the final vowel in the root.

(2.23) Cheremis harmony.

	V	V
Vocalic		
V-Place		

The formulation of Place harmony in (2.23) captures the fact that the rule is assimilatory (since it is formalized as spreading) and that it is a single process. Odden argues against breaking Cheremis harmony into two rules that would spread the features [back] and [round] (or [dorsal] and [labial]) separately, since both rules would have the same lexical exceptions (*kue, kuze, šue,* and *uke*) and both would require a stipulation that non-final /e/ not assimilate (cf. see Odden 1991:273 for details).

2.4.3 The Height constituent

Complete height harmony is found in Kimatuumbi (Odden 1991, 1996), Ewe (Clements 1974), Kashaya (Buckley 1994), Loniu (Hamel 1985), Modern Hebrew (Bat-El 1989), and many other languages (see Clements 1989, Odden 1991, Wiswall 1991, Goad 1993).

Kimatuumbi (Odden 1991) is a Bantu language (P13)[11] spoken in Tanzania that contrasts four vowel heights among the vowels [i u ɪ ʊ ɛ ɔ a].

(2.24) Kimatuumbi vowels.

i		u
ɪ		ʊ
ɛ		ɔ
	a	

Harmony is seen in the examples in (2.25) where the vowels of the passive suffix *-ilw-* and the causative suffix *-iy-* assume the height of a non-low stem-initial vowel. Note that in *kɪɪŋgam-iy-a* 'make follow,' that the [a] of the root blocks the vowel of the causative suffix /iy/ from undergoing harmony.

[11] Bantu languages discussed in this thesis are accompanied by a classification number from Guthrie (1967).

(2.25) Kimatuumbi harmony.

passive		causative	
asim-ilw-a	'borrow'	ut-iy-a	'to make pull'
kun-ilw-a	'dance'	yib-iy-a	'to make steal'
twɪɪk-ɪlw-a	'lift a load'	yʊyʊʊt-ɪy-a	'to make whisper'
ʊʊg-ɪlw-a	'bathe'	bɪɪk-ɪy-a	'to make put'
kɛɛŋgɛɛmb-ɛlw-a	'uproot tubers'	gɔɔnj-ɛy-a	'to make sleep'
bool-ɛlw-a	'tear bark off a tree'	čɛɛŋg-ɛy-a	'to make build'
kɪɪŋgam-a	'follow'	kɪɪŋgam-iy-a	'to make follow'
		kaat-iy-a	'to make cut'

Odden (1991) accounts for the alternations in (2.25) by positing a complete height harmony whereby suffix vowels assimilate completely for height to non-low root vowels. This is formalized by spreading the Height node as in (2.26).

(2.26) Kimatuumbi harmony.

	V	V
Vocalic		
Height		

The formalism in (2.26) allows for a straight-forward account of the alternating surface realization of the suffix vowel in the passive and causative, which predictably varies among [i] ~ [ɪ] ~ [ɛ]. No single feature may spread to realize this range of variation (in the Incremental Constriction Model, or any other approach), thus necessitating that the entire set of height features spread. The formalism in (2.26) captures this, and correctly predicts that the assimilation does not involve place features.

The existence of languages such as Efik, which exhibit total vowel harmony, argues for the recognition of the Vocalic constituent. Harmony in languages such as Cheremis, where vowels assimilate for multiple place features without assimilating for height, argues for the recognition of the V-Place constituent that is independent of all vowel height features. Vowel harmony such as that in Kimatuumbi, in which vowels assimilate completely to the height of another vowel without assimilating to their place, argues for the recognition of a Height constituent that is independent of the vowel place features. Following the work of Clements (1989, 1991), Odden (1991), Wiswall (1991), Goad (1993) and others, the Incremental Constriction Model recognizes the Vocalic, V-Place, and Height constituents (2.16).

2.4.4 Typology of Vowel Height Assimilations

Integral to interpreting (and thus testing) the predictions of the Incremental Constriction Model is establishing a nomenclature of assimilation processes. Clements (1985:231) distinguishes three types of assimilations: complete, partial, and single-feature. He defines complete assimilation as one in which a sound assimilates completely (i.e., for every feature) to another sound, which is formalized as spreading the Root node. Partial assimilation is one in which a sound assimilates for more than one, but not for all features of another sound, formalized as spreading an organizing node. Single-feature assimilations are those in which only a single feature spreads.

For clarity and precision, these types of assimilation are renamed and redefined here. A vowel that assimilates for all features undergoes *Total Harmony*.[12] Total vowel harmony is formalized as spreading the Vocalic node (cf. Efik §2.4.1). Relevant to the current study are two other types of assimilations involving the spreading of organizing nodes: *Place Harmony*, and *Complete Height Harmony*. Place harmony involves the simultaneous assimilation of two[13] or more place features and is formalized as spreading the V-Place node (cf. Cheremis §2.4.2). Complete height harmony is the spreading of the Height node (cf. Kimatuumbi §2.4.3). A height assimilation in which a single height feature spreads is called *Partial Height Harmony*. Partial height harmony is distinct from complete height harmony both in its formalization and its effect. Complete height harmony results in the trigger and target emerging with identical heights in all cases in which harmony applies. In Kimatuumbi, for example, a front vowel surfaces as [i] after [i u], as [ɪ] after [ɪ ʊ], and as [ɛ] after [ɛ ɔ]. In partial height harmony, the target moves toward, but does not attain, the height of the trigger. In Lena Spanish, for example, the vowel [a] raises to [e] before [u], but does not surface as the same height as [u].

(2.27) A typology of vowel harmony.

type of harmony	*what spreads*	*surfaces as*
Total	Vocalic node	identical to trigger
Place	V-Place node	same place as trigger
Complete Height	Height node	same height as trigger
Partial Height	[closed]	one step higher

This dissertation undertakes a thorough investigation of the descriptive and theoretical literature dealing with languages that exhibit vowel height alternations, with the aim of either verifying or falsifying the predictions of the current proposal. The incremental constriction model predicts that some height phenomena should exist, and that others will be found in no language. For those phenomena predicted by this model to exist, this study should document as many examples as possible to establish both the importance of this generalization, and to discern its recurrent properties. For phenomena ruled out by the model, the survey should reveal that they are found in no language.

An examination of vowel height assimilations reveals that not all logically possible height assimilations are found in the world's languages. While one might expect to find both raisings and lowerings among partial height harmonies and complete height harmonies, partial height harmonies that lower their targets are unattested in the world's languages. Complete height harmonies may raise or lower vowels to the same height as the trigger, but all partial height harmonies raise their targets to a height intermediate to the original height and that of the trigger. That is, some languages have complete height assimilation in which, for example, a front vowel is raised to [i] in the vicinity of [i u] but lowered to [e] in the presence of [e o]. Some languages exhibit partial height harmony whereby /ɛ/ is raised to [e] before [i u], but no language lowers /ɪ/ to [e] before [ɛ] (or [a]).

[12] What Clements termed "complete harmony" is now Total Harmony. Current Place Harmony and Complete Height Harmony correspond to Clements's (1985) "partial harmony." Here, Partial Height Harmony is a specific type of "single-feature assimilation" in Clements (1985).

[13] Another type of harmony exists whereby a vowel assimilates for a single place feature, e.g., backness harmony in Turkish. These single-feature harmonies are beyond the scope of this study, and will receive little attention.

(2.28) *Complete Height Harmony*

i → e / __ {e o}

i	u
ɪ	ʊ
e	o
ɛ	ɔ
a	

Hypothetical Counterexample

*ɪ → e / {ɛ a ɔ}

i	u
ɪ	ʊ
e	o
ɛ	ɔ
a	

In addition, all partial raisings involve a shift of exactly one increment. A change of [ɛ] to [e] before [i] is common, but [ɛ] raising to [ɪ] (skipping [e]) before [i] is unattested.

2.5 Summary

This chapter has outlined the properties of the Incremental Constriction Model, and introduced the type of evidence used to support it. The Lena dialect of Spanish exhibits what is referred to as partial height harmony since root vowels raise part way in assimilation to the height of a high vowel suffix. Harmony in Lena Spanish is indicative of a generalization true of all languages exhibiting partial height harmony: all such assimilations involve one-step raising. Only the Incremental Constriction Model captures this generalization. The following chapter discusses a large number of languages that exhibit partial height harmony, all of which follow the one-step raising pattern observed in Lena, thereby bolstering the predictions of the Incremental Constriction Model.

Chapter 3

One-Step Raising

3.0 Introduction

One-Step Raising refers to processes whereby vowels are raised one step in some context. This phenomena provides dramatic support for the Incremental Constriction Model since only this approach to vowel height is able to account for all known cases of one-step raising while correctly predicting that no language exhibits one step lowering nor raisings of more than one step. This chapter examines two phenomena that raise vowels one step. First, in §3.1, partial height harmony is addressed, drawing on evidence from a wide range of diverse languages. This section constitutes the first comprehensive study of partial height assimilation. All languages in this study raise vowels one step in the presence of a higher vowel. In §3.2, other languages are discussed that also exhibit one-step raising, though no overt triggering vowel is present. These cases are examined as morphologically conditioned raising. A number of remaining issues concerning the analysis of height assimilation are addressed in §3.3.

3.1 Partial Height Harmony

Parkinson (1994) distinguishes two types of height harmony, partial and complete height harmony. In *partial height harmony*, a vowel moves toward another vowel but does not surface with the same height as the vowel to which it assimilates. In this type of harmony, the target surfaces with a height between its original height and that of the trigger. In *complete height harmony*, the target vowel surfaces with the exact height as the trigger. In Clements (1991), Odden (1991), and others, complete height harmony is described as the simultaneous assimilation of all height features. Partial height harmony, on the other hand, is described as an assimilation of a single height feature (Parkinson 1994, 1996a). This section deals only with partial height harmony, while complete height harmony is addressed in detail in Chapter 4.

This section examines partial height harmony in a number of languages. In all cases, a vowel moves toward, but does not attain the height of another vowel. In some cases, vowels of more than one height shift toward the height of another vowel, as is the case in Lena Spanish discussed in the previous chapter. This second set of languages poses a problem for approaches that employ multiple features to characterize vowel height since these cases of harmony defy a unified treatment. Models of vowel height that employ disparate features to characterize vowel height cannot describe one-step raising in these

languages in terms of a single feature—each "step" makes reference to a different feature (cf. §2.3). Partial height harmony poses another problem for all previous approaches to vowel height since such models miss the generalization that all cases of partial height harmony involve one-step raising. Models that include a feature that corresponds to "lowered height" incorrectly predict partial lowering to exist (cf. §2.2).

The phenomena addressed in this chapter are discussed within the constraint-based framework of Optimality Theory (Prince and Smolensky 1993, McCarthy and Prince 1995). In this approach, assimilation is characterized in terms of an "alignment" constraint that requires some feature(s) to be aligned to the edges of morphological or phonological categories (Kirchner 1993, Pulleyblank 1993, and others). Mitigating against the satisfaction of alignment are "identity" constraints that strive to keep corresponding input and output segments identical. While a large range of typologically diverse languages are discussed in this section, the alignment constraints required to account for these languages vary from one to another with respect to only three parameters, as follows. All partial height harmony is described in terms of the alignment of [closed] from one vowel to the edge of a morphological category (stem or word), but vary only with respect to (i) whether the instance of [closed] that is aligned is sponsored by a high vowel or a vowel of any height, (ii) the morphological affiliation of the sponsor of the occurrence of [closed] that is aligned, and (iii) whether the instance of [closed] is aligned leftward or rightward.

3.1.1 Lena Spanish

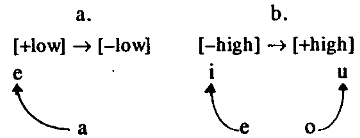
In the previous chapter (§2.3), the Lena dialect of Spanish (Hualde 1989a, b; Kaxe 1989; Dyck 1995; Parkinson 1995a, 1996a; Marínez-Gil 1996) was shown to exhibit partial height harmony. Recall that partial height harmony in Lena targets the stressed vowel of a stem, raising it one step. Vowels of more than one height undergo harmony. The vowel [a] raises to [e] and [e o] raise to [i u]. Since front vowels raise, but do not acquire the backness nor roundness of the trigger [u] in examples such as /nén-u/ → *nín-u* 'child (masculine singular),' the assimilation in (3.1) is a height harmony.

(3.1) Lena Raising revisited.

fem. sg.	*mas. sg.*	*gloss*
gáta	gétu	'cat'
sánta	séntu	'saint'
néna	nínu	'child'
bwéna	bwínu	'good'
kɔ́ša	kúšu	'cripple'
bɔ́na	búnu	'good'

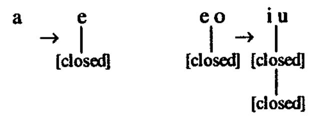
Vowel alternation triggered by suffixes with high vowels is called *metaphony* in the Romance literature. Metaphony, by definition, is assimilatory since the alternations occur only before high vowels. The assimilation in (3.1) is a partial height harmony since the vowel [a] raises one step before [u], and does not assume the height of [u]. The partial height harmony in (3.1) is problematic for the traditional height features [high], [low], and [ATR] since each change in Lena metaphony involves a different feature (3.2). It is argued that the Lena facts defy a unified, non-ad hoc account using traditional height features.

(3.2) Lena Metaphony and the features [high] and [low].



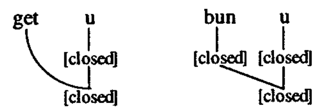
Within the Incremental Constriction Model of vowel height, this harmony is accounted for by reference to a single feature, [closed]. Lena vowels are specified as in (3.3) below so that when each vowel gains an occurrence of [closed] through metaphony, it is realized as one step higher.

(3.3) Lena vowel height.



As an assimilation, the occurrence of [closed] gained by the harmonizing vowels should originate with the triggering vowel. The surface structure, then, is one in which an instance of [closed] is shared between a suffix containing a high vowel and a root vowel.

(3.4) Output of Metaphony.



In constraint-based phonology, the shared structures in (3.4) alter the feature specifications of the root vowel so that the input vowel has a distinct number of occurrences of [closed] from its output corespondent, thus incurring a violation of an "identity" constraint (McCarthy and Prince 1995).

(3.5) Identity of [closed].

IDENT[cl] = an output segment must be specified for an identical number of occurrences of [closed] as its input correspondent.

Some candidates in which IDENT[cl] is violated are preferred in Lena because they satisfy a higher ranked constraint, ALIGN[cl], requiring that an instance of the feature [closed] be shared between the high vowel of the suffix and the stressed vowel. Alignment constraints in general make references to grammatical[14] categories and their edges (McCarthy and Prince 1993:2). Alignment constraints take the form of (3.6).

[14] McCarthy and Prince (1993) make specific reference only to prosodic, morphological, and syntactic categories, though common practice in subsequent work includes distinctive features as well.

(3.6) Generalized Alignment (from McCarthy and Prince 1993).

Align (Category 1, Edge 1, Category 2, Edge 2) = ∀ Category 1 ∃ Category 2 such that Edge 1 of Category 1 and Edge 2 of Category 2 coincide.

In partial height harmony, alignment constraints will always refer to the feature [closed] as "Category 1." As elaborated in the following section (§3.1.3), "Category 1" may specifically denote a high vowel, and may make reference to the morphological affiliation of the instance of [closed]. Thus a constraint requiring that an occurrence of [closed] be shared between a high vowel of a suffix and the stresssed vowel to its left, as in Lena, is stated as in (3.7).

(3.7) Align([closed]$_{max}$ Suffix, L, Stress, L)—Lena.

ALIGN[cl] = for all suffix vowels specified for the maximum number of occurrences of [closed], there exists some occurrence of [closed] such that the left edge of that occurrence of [closed] and the left edge of the stressed vowel coincide.

Candidate (a) in Tableau 3.1 violates IDENT[cl], but is optimal because it satisfies ALIGN[cl], which is ranked above IDENT[cl]. Candidate (b) fails because it violates highly ranked ALIGN[cl].

Tableau 3.1

nen-u → ninu	ALIGN[cl]	IDENT[cl]
a. ☞ nen u [cl] [cl] [cl]		*
b. nen u [cl] [cl] [cl]	*!	

The MAX family of constraints 'maximizes inputs,' or prohibits deletion, by requiring all underlying segments to be present on the surface. McCarthy and Prince (1995) define MAX in terms of segments, but following Lombardi (1995), it is assumed here that MAX is extended to refer to specific features. In this way, the constraint defined in (3.8) is violated by candidates in which an occurrence of the feature [closed] in the input is absent in the output.

(3.8) Maximize [closed].

MAX[cl] = an occurrence of [closed] in the input must have a correspondent in the output.

MAX[cl] is violated by structures such as (c) in Tableau 3.2, where ALIGN[cl] is vacuously satisfied by deleting an occurrence of [closed] from the suffix vowel. Since ALIGN[cl] refers to [closed]$_{max}$, deleting an occurrence of [closed] from a high vowel allows for a vacuous satisfaction of alignment provided that this constraint is evaluated solely on the basis of the surface form.[15] Note that candidates (a) and (c) are equivalent with respect

[15] Another possible analysis assumes that ALIGN[cl] is evaluated on the basis of inputs (cf. McCarthy and

to IDENT[cl], each incurring a single violation, and that MAX[cl] must be active in Lena to rule out (c).

Tableau 3.2

bón-u → bún-u	MAX[cl]	ALIGN[cl]	IDENT[cl]
a. ☞ bún u [cl] [cl] [cl]			*
b. bón u [cl] [cl] [cl]		*!	
c. bón o [cl] [cl]	*!		*

In Lena, the vowel [a] fronts to [e] when it participates in metaphony. This is attributed to the interaction of a group of constraints. The constraint HEIGHTPL (3.9) demands that a non-low vowel be specified for a place feature. This constraint states that a vowel specified for (at least) one occurrence of [closed] implies that it is also specified for [coronal] or [dorsal].

(3.9) Height → Place.

HEIGHTPL = if a vowel is specified for an occurrence of [closed], it must also be a front or back vowel.

In Lena, HEIGHTPL is active, and ranked above IDENT[cor] so that [a] may undergo raising, but must surface with a default vowel place, [coronal]. The fact that [a] fronts, i.e., the fact that [coronal] is the 'default' place for vowels, is attributed to universal markedness constraints (Prince and Smolensky 1993).[16] IDENT[dor] is ranked above IDENT[cor] since candidate (d) is not optimal in Tableau 3.3. In this way, [a] raises and fronts to satisfy ALIGN[closed] without violating HEIGHTPL. The relative ranking of ALIGN[closed], IDENT[dor], and HEIGHTPL is not crucial.

Prince 1995) so that deleting an occurrence of [closed] from a high vowel will not satisfy alignment, but renders a candidate in which this constraint cannot be satisfied by any multiple linking.

[16] See Hume (1994, 1996), who first proposes [coronal] as the default place for vowels, for motivation of this ranking for vowels. See also Repetti (1988) and Hualde (1989a) regarding the backing of [a] to [o] to satisfy HEIGHTPL.

Tableau 3.3

gatu → getu	MAX[cl]	ALIGN[cl]	HeightPl	IDENT[dor]	IDENT[cor]	IDENT[cl]
a. ☞ get u [cl] [cor] [cl] [dor]					*	*
b. gat u [cl] [cl] [dor]		*!				
c. gət u [cl] [cl] [dor]			*!			*
d. got u [cl] [cl] [dor]				*!		*
e. gat o [cl] [dor]	*!					*
f. gæt u [cl] [cor] [cl] [dor]		*!			*	

In the tableau above, all candidates involve the multiple linking of a terminal occurrence of [closed] (or else, no multiple linking at all). The multiple linking of a non-terminal occurrence of [closed] is ruled out by the constraint IDENT[cl], as shown in Tableau 3.4. Candidate (a) satisfies ALIGN[cl] by multiply linking a terminal occurrence of [closed]. Candidate (b) also satisfies ALIGN[cl], but here a nonterminal occurrence of [closed] is multiply linked so that the root and suffix vowels share *two* occurrences of [closed], thereby incurring two violations of IDENT[cl].

Tableau 3.4

gat-u → get-u	ALIGN[cl]	IDENT[cl]
a. ☞ get u [cl] [cor] [cl] [dor]		*
b. git u [cl] [cor] [cl] [dor]		**!

The interaction of IDENT[cl] and ALIGN[cl] captues the all or one generalization discussed above.

In the previous chapter, a derivational account of partial height harmony in Lena was presented. In this section, these same facts were analyzed in terms of constraints within the framework of Optimality Theory (Prince and Smolensky 1993).

3.1.2 Hierarchical representations and tableaux.

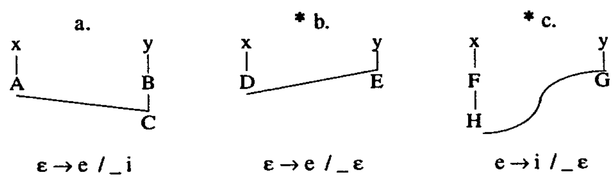
GEN only produces candidates that obey universal, inviolable structural well-formedness conditions, among which is the prohibition that rules out structures in which a higher vowel assimilates to a lower vowel for the feature [closed]. This, the Dominance/Precedence prohibition (repeated in (3.10) from §2.1.5), restricts partial height harmony to cases in which a (relatively) higher vowel spreads [closed] to a lower vowel.

(3.10) Dominance/Precedence prohibition.

> If two elements are in a dominance relation, then those elements are not in a precedence relation. If two elements are in a precedence relation, then they are not in a dominance relation.

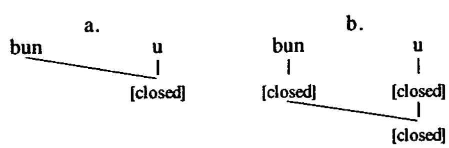
Recall from §2.5.1 that (3.10) allows the structure in (3.11.a) where a higher vowel raises a lower vowel, but rules out (3.11.b, c).

(3.11)



With (2.3) in place, a number of candidates never need to be considered, including candidates in Lena where the suffix [u] shares one occurrence of [closed] with a preceding [i] (since such a candidate, similar to (3.11.b), violates (3.10) and therefore would never be produced by GEN). As the dominance/precedence prohibition is inviolable, the representations in tableau that follow are greatly simplified. Since GEN never produces candidates like (3.11.b, c), ranked constraints do not need to rule them out. Instead, tableaux only consider well-formed structures like that in (3.11.a). As all instances of multiple linking are well-formed, representations can be simplified. The structures similar to that in (3.12.b) below are henceforth replaced by the simplified structure in (3.12.a), both of which represent the word *bunu* 'good.'

(3.12)

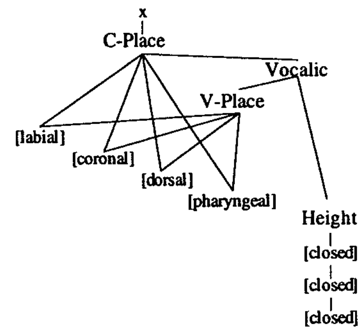


The structure in (3.12.a) is a notational variant of (3.12.b). Some of the structure explicitly depicted in (3.12.b) is assumed in (3.12.a). Assuming the input /bon-u/, (3.12.a) assumes that the left vowel is specified for two instances of [closed], one of which

is present in the input and the other it obtains from the multiple linking depicted. Thus, the specifications that do not change for a given candidate are not depicted.

The simplified structure in (3.12.a) assumes the entire feature-geometric tree[17] proposed in (3.13) (see Clements and Hume (1995) for motivation of this particular structure, though the characterization of height proposed here is different from that assumed by the authors cited). This structure represents the entirety of the Incremental Constriction Model, though all higher structure is not expressly depicted.

(3.13) The Incremental Constriction Model.



The Lena word represented in (3.12.a) is assumed to be fully specified for all features in question so that the stem [u] of *bunu* is specified for two occurrences of [closed] (one of which it was affiliated with this vowel in the input, while the other is shared with the ultima), and the feature [dorsal] (as well as [voice], [sonorant], etc., as appropriate). The [u] in this word is specified for two occurrences of [closed], as well as [dorsal] (and [voice], etc.). Likewise, the intervening [n] is specified for [nasal], etc. The features that do not play a role in the example are omitted, but assumed to be present unless otherwise indicated.

Tableaux are simplified so that only relevant features (or relevant occurrences of features) are mentioned in a given tableau. In all subsequent tableaux, only features that are directly relevant to satisfying the ranked constraints under examination are depicted. All other structure is omitted, and all representations are assumed to be well-formed with respect to universal well-formedness criteria.

3.1.3 Alignment constraints and the feature [closed]

Assimilation is formalized as spreading in derivational non-linear phonology (Goldsmith 1979, Hayes 1986, inter alia). Assimilation in Optimality Theory is most often described in terms of alignment, a constraint that favors linked structures, or sharing (Pulleyblank 1993, Kirchner 1993, among others, but see Cole and Kisseberth 1994). The linked structures that result from assimilation provide a structural account for phenomena

[17] I attribute this idea to No-Ju Kim (pc), who is the first person I am aware of to explicity propose that "structureless" representations in tableaux may actually represent an assumed, fuller organization.

like geminate integrity and inalterability (Schein and Steriade 1986, Hayes 1986, Perlmutter 1995), and restrict the set of possible assimilations to those in which the trigger and surface form of the target share some property. In the absence of evidence to abandon this view, linked structures are adopted here to represent assimilation.

As mentioned above, partial height harmony and complete height harmony differ both in effect and the manner in which each is expressed. In complete height harmony, both the trigger and the target surface with identical height, formalized as sharing a single Height node. In partial height harmony, the target moves toward the height of the trigger, but does not attain that height, so that the two vowels surface with distinct heights. Thus, a vowel that partially assimilates in height surfaces with a height intermediate to its original height and that of the trigger.

(3.14) Assimilation in non-derivational phonology.

Assimilation of an element, *F*, is expressed as the multiple linking of *F*.

An alignment constraint that refers to a feature is satisfied when that feature is "aligned" to both its sponsor (segment with which it is affiliated in the input) and an edge of a domain.[18] As this section is concerned only with partial height harmony, all assimilations discussed here are expressed as an alignment of [closed]. To account for the languages discussed here, constraints referring to the alignment of [closed] vary, from language to language, with respect to a limited number of parameters. Each of these parameters is explained here.

(3.15) Alignment and directionality.

ALIGN ([closed], L/R) = candidates are evaluated for their alignment of an occurrence of [closed] to the left or right edge of the word.

Constraints may evaluate the alignment of [closed] with respect to directionality. In many cases, the direction of alignment is predictable; e.g., in Romance metaphony (such as Lena, discussed above), alignment is evaluated to the left in this case, since only suffixes trigger raising. In other languages, however, the direction in which ALIGN[cl] is evaluated plays a more critical role. In languages such as Setswana, in which alignment is evaluated for all occurrences of [closed] whether affiliated with stem or affix and for vowels of all heights, directionality plays a greater role. In Setswana, [closed] is aligned leftward from any vowel to another (so long as the vowel on the right is higher than that on the left, in accordance with (2.3) above) so that the constraint takes the form of ALIGN[closed](L).

(3.16) Alignment and morphological affiliation.

ALIGN ([closed] Stem/Affix) = alignment is evaluated only for an occurrence of [closed] affiliated with vowels in a particular morphological category.

Constraints may refer to whether an occurrence of [closed] is affiliated with a vowel in some particular morphological domain, e.g., stem, prefix, or suffix. For example, in Romance metaphony, only suffixes trigger raising. Thus, the alignment constraint active in languages that exhibit metaphony takes the form of ALIGN([closed] Suffix), where *Suffix*

[18] For the languages discussed here, the relevant domain is defined as having two edges, one of which is the segment with which [closed] is affiliated in the input, and the other is the begining or end of the word.

allows this constraint to be violated only with respect to occurrences of [closed] affiliated with suffix vowels.

(3.17) Alignment and height of the trigger.

ALIGN ($[\text{closed}]_{max}$) = alignment evaluated only for occurrences of [closed] affiliated with high vowels, i.e., the vowels specified for the maximum number of occurrences of [closed] active in the language.

Constraints (and thus languages) refer only to $[\text{closed}]_{max}$ or to a general occurrence of [closed]. For example, in Nzεbi and in Basque, only high vowels, i.e., vowels specified for the maximum number of occurrences of [closed] active in that language (denoted as $[\text{closed}]_{max}$), trigger raising while in Llogoori and in Setswana, raising is triggered by any higher vowel. Of course only higher vowels are permitted to trigger raising in lower vowels due to the dominance/precedence constraint (2.3). Thus, in Nzεbi, the alignment constraint will take the form of ALIGN[closed] (*max*) and is violated only for the misalignment of [closed] affiliated with a high vowel, while in Setswana, the alignment constraint makes no mention of *max* and is violated by any misalignment of [closed].

For consistency with the standard statement of alignment constraints, the alignment constraints used in this paper will make reference to the left or right edge of the feature [closed], though the particular edge is always predictable from the direction of the sharing.

(3.18) Template for constraints referring to the alignment of [closed].

$$\text{Align[closed]}\left(\begin{matrix}\emptyset\\ \text{max}\end{matrix},\ \begin{matrix}\text{prefix}\\ \text{root}\\ \text{suffix}\end{matrix},\ \begin{matrix}\text{L}\\ \text{R}\end{matrix}\right)$$

The parameters discussed above allow for the logical possibilities in (3.18); a constraint may refer to an occurrence of [closed] that is affiliated with a high vowel or any vowel (ø, or *max*), a vowel in the prefix, root, or suffix, and may require that feature to be aligned leftward or rightward. Each of these possibilities is attested in the languages discussed below.

3.1.4 Servigliano Italian

The Servigliano dialect of Italian (Camilli 1929; Kaze 1989, 1991; Dyck 1995) is spoken in the Marche region of Italy. Servigliano Italian contrasts four heights among the vowels specified in (3.19).

(3.19) Vowels in the Servigliano dialect of Italian.

	i u	e o	ε ɔ	a
[closed]	•	•	•	
[closed]	•	•		
[closed]	•			

Servigliano Italian exhibits metaphony similar to that of Lena Spanish. In Servigliano, a non-low stressed vowel raises one step before a high vowel suffix. The examples in (3.20), from Camilli (1929), illustrate this alternation. Post tonic vowels (right of stressed) are identical to the ultima (Camilli 1929:224-5).

(3.20) Metaphony in Servigliano Italian.

ɛ → e	modɛ́st-a	'modest' (fem. sing.)	modést-u	'modest' (mas. sing.)
	sgwɛ́z-a	'sinister (fem. sing.)	sgwéz-u	'sinister' (mas. sing.)
	pɛ́tten-e	'comb'	péttin-i	'combs'
ɔ → o	sprɔ́t-a	'pedantic' (fem. sing.)	sprót-u	'pedantic (mas. sing.)
	mɔ́r-e	'he dies'	mór-i	'you die'
e → i	mét-o	'I put'	mítt-i	'you put'
	kréd-o	'I believe'	kríd-i	'you believe'
	mé̜tt-a-la	'put it (fem.)'	mítt-i-li	'put them (mas.)'
	mé̜tt-o-lo	'put it (mas.)'	mítt-u-lu	'put it (mas. mass)'
o → u	fjór-e	'flower'	fjúr-i	'flowers'
	spós-a	'wife'	spú-su	'husband'

The examples above illustrate that [ɛ] raises to [e], [ɔ] raises to [o], [e] raises to [i], and [o] raises to [u] when followed by a suffix containing a high vowel. The generalization is that all non-low vowels move one step up the vowel height continuum. These changes represent a partial height harmony in which non-low vowels gain a single occurrence of [closed].

(3.21) Effects of Servigliano metaphony.

```
   ɛ ɔ            e o                 e o            i u
    |      →       |                   |      →       |
[closed]       [closed]            [closed]       [closed]
                   |                   |              |
               [closed]            [closed]       [closed]
                                                      |
                                                  [closed]
```

Servigliano metaphony can be accounted for as the result of an alignment constraint, similar to that posited for Lena Spanish above, preferring candidates in which an occurrence of [closed] is multiply linked between suffixal high vowels and the stressed vowel of the root.

(3.22) Align([closed]$_{max}$ Suffix, L, Stress, L) — Servigliano.

ALIGN[cl] = for all suffix vowels specified for the maximum number of occurrences of [closed], there exists one occurrence of [closed] such that the left edge of that occurrence of [closed] and the left edge of the stressed vowel coincide.

The following tableau illustrates how ranking ALIGN[cl] and MAX[cl] above IDENT[cl] correctly selects candidates in which the stem vowels are one step higher in the input than their input correspondents. Recall from §3.1.2 that only relevant occurrences of [closed] are depicted in Tableau 3.5. Thus, [i] is understood to be specified for three occurrences of [closed] as in (3.19) though only one is mentioned, for example, in candidate (a).

Tableau 3.5

mɔ́r-i → mór-i	MAX[cl]	ALIGN[cl]	IDENT[cl]
a. ☞ mór i [cl]			*
b. mɔ́r i [cl]		*!	
c. mɔ́r e <[cl]>	*!		*
d. múr i [cl] [cl]			**!

In Lena, the constraints IDENT[cl], ALIGN[cl], and HEIGHTPL are ranked so that [a] fronts when raised in Lena. In Servigliano, these same constraints are reranked so that [a] is prevented from undergoing metaphony.

Tableau 3.6

bárc-u → bárc-u	IDENT[dor]	IDENT[cor]	HEIGHTPL	MAX[cl]	ALIGN[cl]
a. ☞ bárc u [dor] [cl]					*
b. bǝ́rc u [dor] [cl]			*!		*
c. bórc u [dor] [cl]	*!		*		
d. bárc o [dor] <[cl]>				*!	
e. bérc u [dor] [cor] [cl]		*!			

As seen by examples such as *bárcu* 'ship (mas. sg.),' the low vowel [a] does not undergo metaphony. The non-participation of [a] is due to the high ranking of IDENT[dor], IDENT[cor] and HEIGHTPL. While not multiply linking an occurrence of [closed] affiliated with a high vowel suffix to [a] incurs a violation of ALIGN[closed], a candidate with only this one violation is preferred to a candidate that violates IDENT[dor], IDENT[cor], or HEIGHTPL. The relative ranking of the identity place constraints and HEIGHTPL is not crucial. The two rankings, Ident[cor] » Align[cl] and Align[cl] » Ident[cor], account for the disparate behavior of [a] in Servigliano (and similar languages discussed below) and in Lena (and similar languages discussed below).

(3.23) The behavior of *a* and constraint ranking.

- Align[cl] » Ident[cor] — *a* raises (and fronts) in harmony.
- Ident[cor] » Align[cl] — *a* does not undergo harmony.

Another analysis of the failure of [a] to undergo metaphony would be to exclude low vowels from the class of undergoers. This might be done by positing a constraint that explicitly prohibits the multiple linking of [closed] to a vowel that is low in the input so that only non-low vowels may undergo the assimilation. Such a 'rich-get-richer' constraint would prohibit [closed] from being multiply linked onto a bare Height node. The treatment proposed above and the 'rich-get-richer' account could be distinguished in a language containing [æ] and exhibiting partial height harmony. If /æ/, a front vowel, were to undergo the process (but /a/ does not), then the HeightPl » Align[cl] analysis is appropriate for that language. If /æ/ and /a/ were both to fail to undergo raising, then an analysis in which low vowels are explicitly excluded is appropriate. The author is aware of no languages which require the explicit reference to low vowels.

The ranking Ident[dor], Ident[cor], HeightPl, Max[cl] » Align[cl] » Ident[cl] is observed in Servigliano.

3.1.5 Nzεbi

Nzεbi (Guthrie 1968, see Clements 1991, Parkinson 1994 for a nonlinear treatment) is Bantu language spoken in Gabon. Nzεbi contrasts four vowel heights among the vowels below. There is a complementary distribution between most vowels in Nzεbi and [ə]. The vowel [ə] does not occur as the first stem vowel (V1), occurring only as the second stem vowel (V2), while [e ε a ɔ o] never appear in V2. The vowel [i] appears in V2 only in certain morphological conditions discussed below. The vowel [u] appears in V2 only when V1 is also [u] (Guthrie 1968).

(3.24) Nzεbi vowels.

	i u	e ə o	ε ɔ	a
[closed]	•	•	•	
[closed]	•	•		
[closed]	•			

Guthrie (1968) documents two speech rates, *normal* and *deliberate* (slow), which affect the appearance of V2. In normal speech, V2 does not surface word finally, e.g., DeliberateSpeech *salə* ~ NormalSpeech *sal* 'work'. The examples in (3.25) are transcribed in deliberate speech.

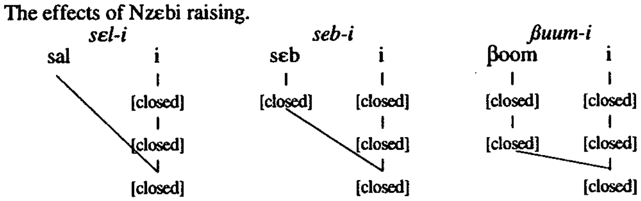
In Nzεbi, all verbs have two forms, which Guthrie calls *simple* (or basic) and *yotized* (in which root vowels are raised). In the simple form, V2 appears as [ə], e.g., *dibəx* 'shut,' whereas in the yotized form, V2 appears as [i], e.g. *dibix*. Examples of verbs in their simple and yotized form are provided in (3.25).

(3.25) Nzεbi.

	simple	yotized	
e → i	betə	biti	'carry'
	bexə	bixi	'foretell'
o → u	βoomə	βuumi	'breathe'
	kolən	kulin	'go down'
ε → e	sεbə	sebi	'laugh'
	βεεdə	beedi	'give'
	kεŋəs	keŋis	'look'
	suεmə	suemi	'hide oneself'
ɔ → o	tɔɔdə	toodi	'arrive'
	mɔnə	moni	'see'
	sɔbəs	sobis	'fortell'
a → ε	salə	sεli	'work'
	baadə	bεεdi	'be'
	laxə	lεxi	'show'
	raxə	rεxi	'fall'
	kasəl	kεsil	'tear'

In the yotized forms, the high vowel in V2 triggers raising of the first stem vowel. The first vowel of the stem raises one step: *a → ε, ε ɔ → e o, e o → i u*. Nzεbi raising is a partial height harmony since the first stem vowel does not always surface as the same height as the trigger [i].

(3.26) The effects of Nzεbi raising.



The multiply linked structures in (3.26) satisfy an alignment constraint that their non-raised counterparts violate. This constraint, Align[cl], is defined below.

(3.27) Align([closed]$_{max}$, L, Word, L)—Nzεbi.

Align[cl] = for all vowels specified for the maximum number of occurrences of [closed], there exists one occurrence of [closed] such that the left edge of that occurrence of [closed] is aligned to the left edge of the word.

In Nzεbi, as in Lena, Align[cl] and HeightPl are not crucially ranked with respect to each other, nor are they ranked with respect to the identity constraints Ident[dor], Ident[cor]. HeightPl and Align[cl] are both ranked above Ident[cl]. This ranking, HeightPl, Ident[dor] » Ident[cor], allows [a] to raise, but requires that it surface as a front vowel (3.23).

Tableau 3.7

sal-i → sɛl-i	MAX[cl]	ALIGN[cl]	HEIGHTPL	IDENT[dor]	IDENT[cor]	IDENT[cl]
a. ☞ ɛ i [cor] [cl]					*	*
b. ɔ i [dor] [cl]				*!		*
c. ɜ i [cl]			*!			*
d. a e <[cl]>	*!					*
e. e i [cl] [cor] [cl]					*	**!
f. a i [cl]		*!				

For stems containing vowels that have a peripheral place feature underlyingly, the identity constraints for vowel place and HEIGHTPL play no role in selecting the optimal candidate. For these forms, ALIGN[cl] and IDEN[cl] determine the surface form.

Tableau 3.8

sɛb-i → seb-i	MAX[cl]	ALIGN[cl]	IDENT[cl]
a. ☞ seb i [cl]			*
b. sɛb i [cl]		*!	
c. sɛb e <[cl]>	*!		*
d. sib i [cl] [cl]			**!

One-step raising in Nzɛbi, exemplified by the examples (3.25) *sebi* 'laugh' and *βuumi* 'breathe' is accounted for by the ranking MAX[cl], ALIGN[cl] » IDENT[cl]. Candidates (e.g., candidates (c) in Tableau 3.7 and Tableau 3.8) which vacuously satisfy ALIGN[cl] by deleting an occurrence of [closed] from the suffix vowel are ruled out because they violate MAX[cl]. Candidates (b) in the two tableaux violate ALIGN[cl] and are thus ruled out. Candidate (d) in Tableau 3.7 satisfies ALIGN[cl] by multiply linking a non-terminal instance of [closed]. Spreading a non-terminal instance of [closed] entails the spreading of that feature and its dependents. Thus, ALIGN[cl] is met, but multiple violations of IDENT[cl] result.[19]

Tableau 3.9

βoom-i → βuum-i	MAX[cl]	ALIGN[cl]	IDENT[cl]
a. ☞ βuum i [cl]			*
b. βoom i [cl]		*!	
c. βoom i <[cl]>	*!		

In Nzɛbi, all non-high vowels raise one step. If vowel height were characterized in terms of the features [high], [low], and [ATR], then Nzɛbi raising would defy a unified treatment, since each vowel that undergoes raising requires reference to a different feature (3.28, as first pointed out in Clements 1991, see also Parkinson 1994).

(3.28) Nzɛbi raising with [high], [low], and [ATR].

a	→	ɛ	[+low]	→	[−low]
ɛ ɔ	→	e o	[−ATR]	→	[+ATR]
e o	→	i u	[−high]	→	[+high]

Because vowel height is characterized in terms of multiple occurrences of the same feature in the Incremental Constriction Model, Nzɛbi raising is described with reference to only one feature, [closed].

3.1.6 SeSotho, Setswana, and Northern Sotho.

The Sotho family of languages is part of the larger Bantu family (Zone S) spoken in southern Africa. This group comprises Sesotho, or Southern Sotho, (Doke 1954, Doke and Mofokeng 1957, Guma 1971, Harris 1987, Clements 1991, and others), Setswana (Cole 1955; Parkinson 1994, 1996b), and Northern Sotho (Mokgokong 1966, Ziervogel 1969, Monareng 1993). These languages have the large vowel inventory in (3.29). The vowels marked with a cedilla correspond to Bantu 'superclosed' vowels. (The correspondence between the symbols used here and those of the authors cited above are in Appendix A.)

(3.29)

i̧		ų
i		u
ɪ		ʊ
e		o
ɛ		ɔ
	a	

[19] A similar candidate is not possible for Tableau 3.8 since the resulting structure would contain a stem vowel specified for more than the maximum number of occurrences of [closed] active in Nzɛbi.

The phonology of the Sotho languages indicates that there are five heights among the vowels in (3.29), as depicted in (3.30). The motivation for grouping the low vowels [ɛ ɔ a] together into a single height is addressed below. The vowels [i u] occur only when derived from /ɪ ʊ/, under conditions examined below, though not all authors discuss this alternation.

(3.30) Sesotho vowels.

	į	ų	i	u	ɪ	ʊ	e	o	ɛ	ɔ	a
[coronal]	•		•		•		•		•		
[dorsal]		•		•		•		•		•	
[closed]	•	•	•	•	•	•	•	•			
[closed]	•	•	•	•	•	•					
[closed]	•	•	•	•							
[closed]	•	•									

The vowels [e o] have a limited distribution in the Sotho languages, but are distinctive. The discussion of the Sotho group begins with Sesotho before moving on to Setswana and Northern Sotho because Sesotho is most often described in the literature. The minimal pairs in (3.31) demonstrate that [e] and [ɛ] as well as [o] and [ɔ] are contrastive.

(3.31) Phonemic status of *e o*.

ena	'these' NCLASS 2
ɛna	'become rich'
sela	'that yonder' NCLASS 4
sɛla	'buy food at the time of scarcity'
hona	'this' NCLASS 7
hɔna	'it' NCLASS 7

The vowels [ɛ ɔ] never occur before a higher vowel. There is an alternation in which [ɛ ɔ] appear before other vowels of this height (i.e., [ɛ a ɔ]), but surface as [e o] when followed by any higher vowel ([į ɪ ų ʊ]). This alternation is illustrated by the examples below. (The initials DM indicate that these data are from Doke and Mofokeng (1957), G denotes Guma (1971), H denotes Harris (1987), and CM denotes Clements (1991).)

Notice that the vowels (ɪ ʊ) of the negative suffix and reversive suffix (respectively) trigger raising, as do [į ų] of the causative and agentive suffixes. (The raised vowels are underlined as an aide to the reader.)

(3.32) ɛ ɔ → e o

DM	fɛl-a	'come to an end'	fe̱l-įsa	'finish'
	ɛm-a	'stand'	e̱m-ɪ	'standing'
	rɔk-a	'praise'	ro̱k-įle	'praised'
	kɪ-a-bɔn-a	'I see'	ha-kɪ-bon-ɪ	'I don't see'
	qɛk-a	'entice'	qe̱k-ʊlʊh-a	'avoid'
	bɔf-a	'inspan'	bo̱f-ʊll-a	'outspan'
	hlɔp^{h}-a	'arrange'	hlo̱p^{h}-ʊll-a	'unpack'
	kɔb-a	'bend'	ko̱b-ʊll-a	'straighten'
G	rɛm-a	'chop down'	re̱m-įle	'have chopped down'
	mɛm-a	'invite'	me̱m-įs-a	'cause to invite'
	rɔk-a	'praise'	sɪ-ro̱k-į	'a praise-poet'
	bɔl-a	'rot'	sɪ-bo̱l-ų	'rotten thing'

H	bɔn-a	'see'	sɪ-bo̱n-į	'thing that sees'
	p^{h}ɛh-a	'cook V'	mʊ-p^{h}e̱h-į	'cook N'
	pɔt-a	'go round'	po̱t-ɪ	negative
			po̱t-ʊlʊl-a	reversive
			po̱t-įs-a	causative
	fɛr-a	put rafters on'	fe̱r-ɪ	negative
			fe̱r-ʊll-a	reversive
			fe̱r-įs-a	causative
CM	sɛb-a	gossip'	mʊ-se̱b-į	'gossiper'
	bɛtl-a	'sharpen'	be̱tl-ųw-e	'has been sharpened'
			be̱tl-ɪ	'not sharpen'
	ɛp-a	'dig'	e̱p-ʊll-a	'dig out'
	kɔb-a	'bend'	ko̱b-ʊll-a	'unbend'
	hlɔhlɔn-a	'itch'	hlo̱hlo̱n-ɪ	'not to itch'

Examples such as *ratįle* demonstrate that the vowel [a] does not undergo raising. Strings of low vowels all raise before an appropriate vowel (Harris 1987, Clements 1991), as illustrated by examples of the type *hlɔhlɔna* 'itch' versus *hlohlonɪ* 'not itch.'

In addition to triggering the raising of [ɛ ɔ], the vowels [ɪ ʊ] also undergo raising when followed by a superclosed vowel. This alternation, in which [ɪ ʊ] surface as [i u] before [į ų], is seen in the examples in (3.33). Strings of high vowels raise before the superclosed vowel, as seen in *sitsumį* 'hunter,' *sisiɲį* 'culprit,' and *pubulį* 'moaning.'

(3.33) ɪ ʊ → i u

G	-lɪm-	'cultivate'	mulimį	'farmer'
	-tsʊm-	'hunt'	sitsumį	'hunter'
			sisiɲį	'culprit'
			lifų	'death'
			sifųba	'chest'
			pulį	'goat'
			bubį	'wasp'
			pubulį	'moaning'
CM	bɪl-a	'boil'	-bid-įle	'have boiled'
			-bid-įs-a	'cause to boil'
	nʊk-a	'season'	-nuk-įle	'have seasoned'
			-nuk-įs-a	'cause to season'

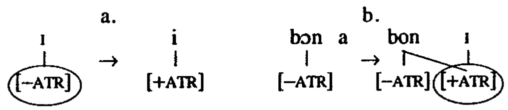
The vowels [ɪ ʊ] raise when followed by raised [i u], but do not raise when followed by raised [e o], as the examples below (from (3.32) and (3.33) above) demonstrate. This argues against an account of Sesotho based on the feature [ATR], since in languages that exhibit true cross-height harmony, such as Akan, "raising" is triggered both by high and low vowels of the appropriate [ATR] set (Stewart 1967). That is, the process raising *ʊ* → *u* is triggered both by [i u] as well as [e o] in Akan, while in Sesotho, only higher vowels trigger the process, suggesting that the assimilation is of height, and not tongue root position.

(3.34) Raising context for high vowels.

mu̱	li̱m-į	'farmer'
si̱	tsu̱m-į	'hunter'
mʊ	ro̱k-į	'poet'
sɪ	bo̱d-į	'rotten thing'

A more serious problem for the [ATR] analysis lies in the behavior of [ɪ ʊ] which both trigger and undergo raising. In an account based on [ATR], these vowels would require a contradictory [ATR] specification since they must at once be specified as [−ATR] to undergo raising and be specified as [+ATR] to trigger the raising of [ɛ ɔ].

(3.35)



Sesotho, then, exhibits partial height harmony whereby [ɛ ɔ] are raised to [e o], and [ɪ ʊ] are raised to [i u] when followed by higher vowels. Similar height assimilation is found in Setswana and Northern Sotho, as discussed below. An account of all three languages is provided following a discussion of partial height harmony in each of the languages.

Setswana (Cole 1955, Parkinson 1996) is spoken in Botswana. Setswana exhibits the same harmony as discussed above for Sesotho. The raising of [ɛ ɔ] to [e o] is illustrated in the examples in (3.36).

(3.36) ɛ ɔ → e o

a.	ɛm-a	'stand'	k'ɪ-e̱m-ɪ	'I am standing'
	ep'-a	'dig'	e̱p'-ʊlʊl-a	'dig out'
	rɛk'-a	'buy'	xa-k'ɪ-re̱k'-ɪ	'I do not buy'
	bɔn-a	'see'	xa-k'ɪ-bo̱n-ɪ	'I do not see'
	bɔf-a	'tie'	bo̱f-ʊlʊl-a	'untie'
	kɪ-tlɔk'ɔmɛl-a	'I look after'	xa-kɪ-tlo̱k'o̱me̱l-ɪ	'I don't look after'
b.	rɛk'-a	'buy'	mʊ-re̱k'-i̱	'one who buys'
	lɔw-a	'bewitch'	mʊ-lo̱w-i̱	'witch'
	xʊ-rɛm-a	'to chop'	re̱m-i̱le	'chopped'
	lɛm-a	'spoil'	xʊ-le̱m-i̱-a	'to cause to spoil'
	bɔl-a	'rot'	sɪ-bo̱l-u̱	'rotten thing'

As in Sesotho, the vowels [ɪ ʊ] also undergo raising as seen in the examples in (3.37).

(3.37) *ɪ ʊ → i u*

lɪf-a	'pay (a fine)'	mu̱-li̱f-i̱	'one who pays'
xʊ-rʊk'-a	'to sew'	mu̱-ru̱k'-i̱	'tailor'
tsʊm-a	'hunt'	tsu̱m-i̱s-a	'cause to hunt'
xʊ-fɪrɪ-a	'to propose love'	mu̱-fi̱ri̱-i̱	'one who proposes love'
xʊ-fʊfʊts-a	'to massacre'	mu̱-fu̱fu̱ts-i̱	'one who massacres'

The account of the Setswana facts is presented following a description of the Northern Sotho facts. Northern Sotho (Mokgokong 1966) exhibits the same harmony as found in Sesotho and Setswana. The vowels [ɛ ɔ] raise to [e o] when followed by any higher vowel. The examples in (3.38) illustrate this.

(3.38) ɛ ɔ → e o

rɛk-a	'buy'	re̱k-i̱lɛ	'bought'
		re̱k-iʃ-a	'sell'
		xa-kɪre̱k-ɪ	'ɪ do not buy'
rɛm-a	'chop	re̱m-i̱lɛ	'chopped'
ɛm-a	'stand'	e̱p-ʊlla	'sit down'
rɔb-a	'break'	ro̱b-i̱lɛ	'broken'
rɔr-a	'roar'	ro̱r-ilɛ	'roared'
βɔn-a	'see'	βo̱n-iʃ-a	'show'
		xa-kɪ-bo̱n-ɪ	'ɪ do not see'
bɔf-a	'tie'	bo̱f-ʊll-a	'untie'

The high vowels [ɪ ʊ] also raise when followed by a higher vowel.

(3.39) ɪ ʊ → i u

lɪf-a	'pay a fine'	mu̱-lif-i̱	'fine payer'
fɪt-a	'pass'	fi̱t-i̱lɛ	'passed'
rʊk-a	'sew'	ru̱k-i̱	'tailor'
		ru̱k-i̱lɛ	'sewn'

An analysis of the Sotho languages within the Incremental Constriction Model is straightforward. Here, raising is described as an increase in the number of occurrences of [closed]. The vowels [ɛ ɔ] are specified for no instances of [closed] underlyingly, but surface as [e o] when followed by a higher vowel.

(3.40) Align([closed], L, Word, L)—Sesotho.

ALIGN[cl] = for all vowels specified for [closed], there exists one occurrence of [closed] such that the left edge of that occurrence of [closed] is aligned to the left edge of the word.

The alignment constraint that drives the multiple linking of [closed] in Sesotho is provided in (3.40). This constraint does not require that the vowel sharing its occurrence of [closed] be a high vowel since there is no mention of $[closed]_{max}$.

Tableau 3.10

bɔn-ɪ → bon-ɪ	ALIGN[cl]	IDENT[cl]
a. ☞ bo̱n ɪ [cl]		*
b. bɔn ɪ [cl]	*!	
c. bɔn ɛ <[cl]> <[cl]>		**!
d. bɔn e [cl] <[cl]>		**!

bɔn-ɪ → bon-ɪ	Align[cl]	Ident[cl]
e. bun ɪ [cl] [cl]		**!

Candidate (a) in Tableau 3.10 is optimal in spite of violating Ident[cl] since it satisfies the high ranked Align[cl] constraint. Candidate (b) is ruled out because it violates Align[cl]. The remaining candidates are ruled out because they incur multiple violations of Ident[cl]. Two occurrences of [closed] are deleted in (c), thus changing the height specification of the suffix vowel. Each deletion of an occurrence of [closed] incurs an Ident[cl] violation; the second violation of Ident[cl] takes candidate (c) out of contention since the winning candidate violates this constraint only once. Likewise, (d) and (e) are ruled out for their second Ident[cl] violations. Candidate (d) deletes one occurrence of [closed] and multiply links another, thereby incurring two Ident[cl] violations. Candidate (e) spreads a non-terminal occurrence of [closed], thereby incurring two Ident[cl] violations for the root vowel.

In Sesotho, as in Servigliano Italian, the vowel [a] does not undergo raising due to the ranking of Ident[cor], Ident[dor], and HeightPl above Align[cl] (3.23).

Tableau 3.11

xʊ-bal-ɪ → xʊ-bal-ɪ	Iden[dor]	Ident[cor]	HeightPl	Align[cl]
a. ☞ a ɪ [cl]				*
b. ə ɪ [cl]			*!	
c. e ɪ [cor] [cl]		*!		
d. e ɪ [dor] [cl]	*!			

3.1.7 Llogoori

Llogoori (Leung 1986) is a Bantu (E41) language spoken in Kenya, and is a member of the Luhya group. Llogoori contrasts the vowels in (3.41),[20] and requires three occurrences of [closed] to characterize its inventory.

[20] Llogoori, like many Bantu languages (e.g., Kikuyu, Kimatuumbi) contrasts three heights where the upper "mid" vowels are pronounced as *ɪ ʊ* and the low mid vowels are *ɛ ɔ*. Leung (1986) uses the symbols *e o* for the lower mid vowels while *ɛ ɔ* are used here for consistency with the vowels represented by these symbols.

(3.41) Llogoori vowels.

	i u	ɪ ʊ	ɛ ɔ	a
[closed]	•	•	•	
[closed]	•	•		
[closed]	•			

The examples of Llogoori verbs in (3.42) consist of a pronominal prefix, a verb stem, and a final vowel marking the subjunctive mood. The final vowel for many tenses is [a], but in the examples from the subjunctive below, the final vowel surfaces as [ɛ] or [ɪ].

(3.42) Llogoori partial height harmony.

a. kɛ-vɛg-ɛ 'shave it'
kɛ-rɛɛt-ɛ 'bring it'
kɛ-nɔɔr-ɛ 'obtain it'
kɪ-karag-ɛ 'cut it'
kɪ-saamb-ɛ 'burn it'

b. kɪ-guut-ɪ 'defeat it'
kɪ-vis-ɪ 'hide it'
kɪ-guriz-ɪ 'sell it'
kɪ-vis-ɪ 'hide it'
kɪ-duɣ-ɪr-ɪ 'hit for it'
kɪ-kɪn-ɪr-ɪ 'play for it'
kɪ-rʊm-ɪ 'bite it'

The final vowel is always a front vowel in the subjunctive, and surfaces as [ɛ] when preceded by a vowel of the same or lower height (3.42.a). The final vowel raises to [ɪ] when preceded by a higher vowel (3.42.b). Llogoori raising (3.42) constitutes a partial height harmony since *ɛ* does not raise to the same height as the high vowel trigger in *kɪvisɪ* 'hide it.' Examples such as *kɪrʊmɪ* 'bite it' indicate that the suffix assimilates in height to a preceding high vowel, but does not assimilate to the place of that vowel.

The alternations in (3.42) cannot be analyzed as a lowering in which /ɪ/ lowers to [ɛ] before [ɛ a ɔ]. Llogoori does exhibit a complete lowering of [ɪ] to [ɛ], but only after [ɛ ɔ]. As shown in (3.43), the vowel [a] does not trigger complete lowering. The processes at work in (3.42) and (3.43) are distinct, demonstrating that the alternations above constitute a one-step partial raising.

(3.43) Complete lowering in Llogoori.

kɔ-mɔrɔm-ɛr-a 'to speak for'
kɔ-vɛg-ɛr-a 'to shave for'

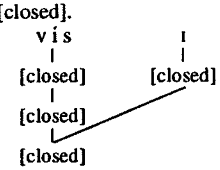
ku-kɪn-ɪr-a 'to play for'
ku-vis-ɪr-a 'to hide for'
ku-karag-ɪr-a 'to cut for'

Since Llogoori raising (3.42) is assimilatory, the surface form of *visɪ* should have some structure shared between the triggering [i] and the harmonizing [ɪ]. As a partial height

[21] The alternation of the prefix between *kɪ ~ kɛ* reflects a complete height harmony in which /ɪ/ completely lowers to [ɛ] before [ɛ ɔ].

harmony, the resulting structure appears as in (3.44), with one occurrence of [closed] shared between the root vowel and the harmonizing suffix.

(3.44) Sharing one instance of [closed].



(3.45) Align([closed], R, root, R) — Llogoori.

ALIGN[cl] = for all vowels specified for [closed], there exists one occurrence of [closed] for which the the right edge of that feature and the right edge of the word coincide.

ALIGN[cl] is satisfied by candidates, produced by GEN, where a single occurrence of [closed] is shared between the root and the suffix. In Tableau 3.12, ALIGN[cl] is satisfied by the first candidate, (a), but is violated in (b) where no sharing takes place.

Tableau 3.12

vis-ɛ → vis-ɪ	ALIGN[cl]	IDENT[cl]
a. ☞ vis ɪ [cl]		*
b. vis ɛ [cl]	*!	
c. vis i [cl] [cl]		**!

Candidate (c) violates IDENT[cl] twice since it satisfies ALIGN[cl] by multiply linking a non-terminal occurrence of [closed], thereby sharing that occurrence of [closed] and its dependent. In this way, the final vowel is specified for two more occurrences of [closed] in the output than is its input correspondent. Multiple linking of non-terminal [closed] is always dispreferred since ALIGN[cl] can be satisfied by aligning a terminal occurrence of [closed].

In Llogoori, HEIGHTPL is ranked higher than ALIGN[cl] as illustrated in Tableau 3.13. The relative high ranking of HEIGHTPL ensures that /a/ does not raise in Llogoori.

Tableau 3.13

vis-a → vis-a	HEIGHTPl	IDENT[dor]	IDENT[cor]	ALIGN[cl]
a. ☞ vis a [cl]				*
b. vis ə [cl]	*!			
c. vis ɛ [cl] [cor]			*!	
d. vis ɔ [cl] [dor]		*!		

The universal prohibition against lower vowels raising higher vowels (2.3) and the high ranked HEIGHTPL constraint allow only the suffix [ɛ] to undergo raising,[22] and only when preceded by a higher vowel. Thus, the optimal candidate generated from an input of the form *kɪ-vis-ɛ* is one in which the suffix is raised, as in *kɪ-vis-ɪ* 'hide it.'

3.1.8 Basque

Basque (Hualde 1991, 1993; Saltarelli 1988; Bonet 1993) is a language isolate spoken in northern Spain, and southwestern France. Basque has the vowels in (3.46), though some dialects have contrastive length and others also contain [ü] (see Hualde 1991, 1993 for discussion).

(3.46)

	i u	e o	a
[closed]	•	•	
[closed]	•		

Basque exhibits a number of vowel alternations; of immediate concern here is a process of low vowel assimilation in which [a] raises to [e] when preceded by a high vowel. Low vowel raising is found in a number of dialects of Basque.

[22] The final vowel in Llogoori has only two qualities underlyingly, [a] and [ɛ].

(3.47) Low Vowel Raising.

Baztan			
fabrikȩ	'factory'	*cf.* fabrika	*in Standard dialect*
mugȩ	'limit'	*cf.* muga	
ikeratu	'frighten'	*cf.* ikaratu	
irȩbazi	'to earn, win'	*cf.* irabazi	
belaunikȩtu	'to kneel'	*cf.* belaunikatu	
ikȩtz	'coal'	*cf.* ikatz	
buru-ȩ	'head (abs.)'	*cf.* gogo-a	'spirit'
buru-ȩk	'heads (abs.)'	*cf.* goko-ak	'spirits'
afari-xkȩ	'little dinner'	*cf.* larra-xka	'little prairie'
lagun-tzȩ	'help'	*cf.* arran-tza	'fishing'
buru ȩu	'this head'	*cf.* baso au	'this forest'
mendi bȩt	'one mountain'	*cf.* baso bat	'one forest'
torri dȩ	'he has come'	*cf.* gan da	'he has gone'
Arbizu			
ikȩśi	'to learn'	*cf.* ikasi	*in Standard*
išȩn	'to be'	*cf.* izan	
bišȩr̄	'beard'	*cf.* bizar	
Gernika			
išȩn	'to be'	*cf.* izan	
faβr̄ikȩ	'factory'	*cf.* fabrika	
tšišpȩ	'spark'	*cf.* txispa	
laɣun-ȩ	'the friend (abs.)'	*cf.* gišon-a	'the man'
laɣun-ȩk	'the friends (abs.)	*cf.* gišon-ak	'the men'
lekù-ȩn	'in the place'	*cf.* bašo-an	'in the forest'
lekù-tȩn	'in places'	*cf.* bašo-tan	'in forests'
ar̄i-kȩ	'throwing stones'	*cf.* šalto-ka	'jumping'
lagun-tšȩ	'help'	*cf.* eškon-tša	'marriage'
lagɣum bȩt	'one friend'	*cf.* ašto βat	'one donkey'
Ondarroa			
laɣun-ȩ	'the friend'	*cf.* gišon-a	'the man'
ar̄i-kȩ	'throwing stones'	*cf.* pelota-ka	'throwing a ball'
biɲȩ	'two by two'	*cf.* ba-na	'one by one'

See Bonet (1993) for discussion of the domain in which partial height harmony takes place in Basque. The data above demonstrate that the process is robustly attested in several dialects.

(3.48) Align([closed]$_{max}$, R, word, R)

ALIGN[cl] = for all vowels specified for the maximum occurrences of [closed], there exists an occurrence of [closed] such that the right edge of this feature and the right edge of the word coincide.

Since [a] participates in partial height harmony in Basque, ALIGN[cl] and HEIGHTPL must be ranked higher than IDENT[cor].

Tableau 3.14

laɣun-a → laɣun-e	MAX[cl]	ALIGN[cl]	HEIGHTPL	IDENT[dor]	IDENT[cor]	IDENT[cl]
a. ☞ u e [cl] [cor]						*
b. u a [cl]		*!				
c. u o [cl] [dor]				*!		*
d. u ə [cl]			*!			*
e. o a <[closed]>	!*					*
f. u i [cl] [cl] [cor]					*	**!

Low vowel assimilation does not apply to mid vowels, i.e., /laɣun-en/ 'friend (dat. indefinite)' surfaces as *laɣunen* (cf. *gišon-en* 'man (dat. indefinite),' and not as **laɣunin*. This effect can be achieved by positing another constraint that prohibits the multiple linking of [closed] between a high and an underlying mid vowel as in (3.49), since, in fact, no assimilation occurs between high and mid vowels (iCi and uCu sequences may arise as a result of place assimilation which is not in conflict with (3.49) (Saltarelli 1988:281)).

(3.49) *i͜e.

*i͜e = an occurrence of [closed] affiliated with a vowel specified for the maximum number of occurrences of [closed] may not be multiply linked to a vowel specified for [closed] in the input.

* i i
[closed] [closed]
[closed]

The constraint in (3.49) is not violated by *laɣuna* → *laɣune* (candidate (a) in Tableau 3.14) since the vowel to which [closed] is multiply linked is not specified for [closed] in the input. *i͜e must be ranked above than ALIGN[cl] in order to rule out **laɣunin*.

Tableau 3.15

lagunen	*i͜e	ALIGN[cl]
a. ☞ lagun en [cl]		*

lagunen	*ie	ALIGN[cl]
b. lagun in [cl]	*!	

By ranking the constraint *ie above ALIGN[cl], mid vowels are correctly prevented from undergoing harmony, as demonstrated in Tableau 3.15.

3.1.9 Woleaian

Partial height harmony is also found in Woleaian (Sohn 1971), a Micronesean language spoken in the Woleai atol. Woleaian has the vowels in (3.50) where [ɨ] is a high, central vowel.

(3.50) Woleaian vowels.

i	ɨ	u
e		o
	a	

Harmony applies in the examples in (3.51) where the low vowel [a] raises when it occurs between two high vowels. The final root vowel in *wilima-* is low and preceded by a high vowel [i], but does not raise when followed by another low vowel. It surfaces as [e] when a high vowel in a suffix places it between high vowels. The assimilation is partial since [a] does not surface as a high vowel. (See Sohn for discussion of word-final vowel and consonant alternations.)

(3.51) Partial Harmony in Woleaian.

/wilima-ji/	→	ilimej	'my drinking object'
/wilima-mu/	→	ilimem^w	'your (s) drinking object'
/wilima-ca/	→	ilima-ʃ	'our drinking object'

Since [a] raises to [e] between two non-front vowels in *wilima-m^w* 'your drinking object,' this change must be an assimilation of height and not place. Since [a] raises to [e] in assimilation of height, it is clear that the two vowels have different phonemic heights. Woleaian vowels are specified as in (3.52).

(3.52) Woleaian vowels.

	i	ɨ	u	e	o	a
[coronal]	•			•		
[dorsal]			•		•	
[closed]	•	•	•	•	•	
[closed]	•	•	•			

Partial height harmony in Woleaiain is described in terms of an alignment constraint that requires a high vowel to share one occurrence of [closed] with vowels to the left (3.53).

(3.53) Align([closed]$_{max}$, L, word, L)—Woleaian.

ALIGN[cl] = for all vowels specified for the maximum number of [closed], there exists one occurrence of [closed] for which the the left edge of that feature and the left edge of the word coincide.

Recall that partial height harmony only applies when /a/ is between two high vowels. This reflects a constraint in Woleaian, *TROUGH, which prohibits a sequence of vowels of high-low-high heights. This constraint is formulated below. While (3.54) refers to vowel height, this constraint appears to be more general, mitigating against troughs along other phonetic dimensions. *TROUGH may be at work in intervocalic spirantization in languages such as Spanish and Somali. David Odden (pc) points out that Bantu exhibits two processes that might be characterized as an avoidance of a trough: the raising of a low tone to downstepped high between high tones (e.g., HLH → HꜜHH) and Meinhof's Law, which converts NCVN → NVN.

(3.54) Avoid troughs.

***TROUGH** = avoid sequences of syllables in which a bare height node is between two vowels specified for the maximum number of occurrences of [closed].

The *TROUGH constraint (3.54), while providing an account of the facts, does not completely explain the phenomenon. The constraint affects only low vowels between high vowels, but does not effect mid vowels. This might be attributed to a gradient property of the constraint such that a bear Height node between high vowels is a more egregious violation of TROUGH than is a Hieght node with an occurrence of [closed] between to high vowels.

In Woleaian, IDENT[cl] is ranked above ALIGN[cl] while *TROUGH is ranked above each of these constraints. As a result, ALIGN[cl] is always violated unless its satisfaction averts a violation of *TROUGH.[23]

Tableau 3.16

i a i → i e i	*TROUGH	IDENT[cl]	ALIGN[cl]	HEIGHTPL	IDENT[cor]
a. ☞ i e i [cor] [cl]		*			*
b. i a i	*!		*		
c. i ə i [cl]		*		*!	

Higher ranking IDENT[cl] prevents non low vowels from satisfying alignment. This constraint ranking in Woleaian allows only a low vowel between high vowels to participate in the harmony, i.e., satisfy ALIGN[cl]. This alignment constraint requires a single instance of [closed] to be multiply linked between a high vowel trigger and a low vowel. The vowel [a] uniquely undergoes partial height assimilation, raising one step between high vowels.

[23] It is possible that *TROUGH by itself could motivate the multiple linking of [closed]. In such an analysis, though, an instance of [closed] might be inserted to satisfy *TROUGH as well. Since ALIGN[cl] is present in Woleaian (as are all constraints (Prince and Smolensky 1993)), ranking this constraint highly enough that it is active in the language ensures that *TROUGH is satisfied via multiple linking, consistent with the fact that this process is assimilatory.

Tableau 3.17

i e i → i e i	*Trough	Ident[cl]	Align[cl]	HeightPl	Ident[cor]
a. ☞ i e i			*		
b. i i i [cl]		*!			

The correct results are achieved for Woleaian by the crucial ranking of the constraint constraint among more familiar constraints. *Trough and Ident[cl] are ranked above Align[cl] in Woleaian.

3.1.10 Kikuria

Partial height harmony is also found in the Bantu language (E43) Kikuria (Chacha and Odden 1994, Cammenga 1994) spoken in Kenya. Kikuria has a seven vowel system specified in (3.55) within the Incremental Constriction Model.

(3.55) Kikuria vowels.

	i u	e o	ɛ ɔ	a
[closed]	•	•	•	
[closed]	•	•		
[closed]	•			

Examples showing partial height harmony in Kikuria are provided below. (Complete height harmony in Kikuria is discussed in Chapter 4). In these examples, the stem vowels [ɛ ɔ] are raised to [e o] and [e o] are raised to [iu] before the agentive suffix [i]. (The raised vowels are underlined.)

(3.56) Partial height harmony in Kikuria.

	infinitive	*agentive* -i	*gloss*
a.	oko-rɔ́g-a	omo-ró̲g-i	'witch'
	oko-gɔ́ɔ́gá	oko-góóg-i	'slaughter'
	oko-gɔ́ɔ́t-á	omo-gó̲ó̲t-i	'hold'
	ogo-tɛ́rɛ́k-a	omo-té̲ré̲k-i	'brew'
	oko-gɛ́s-a	omo-gé̲s-i	'harvest'
	ogo-tɛ́ɛ́m-á	omo-té̲é̲m-i	'hunt mushrooms'
b.	oko-sóók-á	u̲mu̲-sú̲ú̲k-i	'respect'
	oko-hóór-a	u̲mu̲-hú̲ú̲r-i	'thresh'
	ogo-táčór-a	omo-táčú̲r-i	'untie'
	oko-rém-a	u̲mu̲-rí̲m-i	'cultivate'
	ogo-tégét-ǎ	u̲mu̲-tí̲gí̲t-i	'be late'

As the vowels [ɛ ɔ] do not surface with the same height as the trigger [i] in (3.56), this constitutes a partial height assimilation. The raising of /ɛ ɔ/ to [e o] as well as the raising of /e o/ to [i u] involves a one-step change expressed as the addition of a single occurrence of [closed]. The multiple linking of [closed] is preferred by an alignment constraint.

(3.57) Align([closed]max, L, word, L) — Kikuria.

Align[cl] = for all vowels specified for the maximum number of [closed], there exists one occurrence of [closed] for which the left edge of that feature and the left edge of the word coincide.

As the vowel [a] does not participate in harmony, the constraints Ident[dor] and Ident[cor] are ranked higher than Align[cl] in Kikuria, as illustrated in Tableau 3.18. As in the Sotho languages, NoGap is ranked highly enough to prevent height harmony from applying over [a] in examples such as *omotáčuri* 'cause to untie,' where the [a] "blocks" the prefix vowels from undergoing the assimilation.

Tableau 3.18

-rɔg-i- → -rog-i-	Max[cl]	HeightPl	Ident[dor]	Ident[cor]	Align[cl]	Ident[cl]
a. ☞ o i [cl]						*
b. ɔ i [cl]					*!	
c. ɔ e <[cl]>	*!					*
d. u i [cl] [cl]						**!

3.1.11 Gitonga

A partial height harmony, similar to that discussed above in Kikuria, is found in Gitonga (David Odden pc, Parkinson 1996c), a Bantu language (S62) spoken in Mozambique. Gitonga also has a seven vowel system (3.58).

(3.58) Gitonga vowels.

	i u	e o	ɛ ɔ	a
[closed]	•	•	•	
[closed]	•	•		
[closed]	•			

Partial height harmony in Gitonga raises the vowels [ɛ ɔ] to [e o] when followed by a high vowel. In the examples below, the high vowels of the locative suffixes *-ni* and *-tunu* trigger the one-step shift of the root vowels. When strings of [ɛ ɔ] appear in a stem, the entire string raises one step before a high vowel, e.g., *sɔmbɔ-ni* → *sombo-ni* 'in clothes.' Examples like *gilato-ni* show that the low vowel [a] does not undergo partial height harmony in Gitonga. (The raised vowels are underlined.)

(3.59)

root	*'in X'*	*'where the X are'*	
sɔmbɔ	sọmbọ-ni	sọmbọ-tunu	'clothes'
gilatɔ	gilatọ-ni	gilatọ-tunu	'shoe'
gipɛtɔ	gipẹtọ-ni	gipẹtọ-tunu	'circle'
ndzɛvɛ	ndzẹvẹ-ni	ndzẹvẹ-tunu	'ear'

Gitonga raising is accounted for by positing a constraint, (3.60), that prefers candidates in which a high vowel shares one occurrence of [closed] with a preceding vowel.

(3.60) Align([cl]$_{max}$, L, word, L) — Gitonga.

ALIGN[cl] = for all vowels specified for [closed], there exists one occurrence of [closed] for which the the left edge of that feature and the left edge of the word coincide

ALIGN[cl] is ranked above IDENT[cl] as demonstrated in the following tableau. Candidate (a) in Tableau 3.19 is optimal in spite of incurring two IDENT[cl] violations because it satisfies the higher ranked ALIGN[cl] and MAX[cl]. Candidate (b) is ruled out in spite of violating IDENT[cl] only once since [closed] is misaligned. Candidate (e) satisfies ALIGN[cl] by multiply linking a non-terminal instance of [closed], but is sub-optimal since it incurs four IDENT[cl] violations. Candidate (f), in which non-terminal [closed] is spread, is ruled out since it incurs no more IDENT[cl] violations than the winning candidate, but does so by mis-aligning [closed].

Tableau 3.19

sɔmbɔni → somboni	MAX[cl]	ALIGN[cl]	IDENT[cl]
a. ☞ o o i [cl]			**
b. ɔ o i [cl]		*!	*
c. ɔ ɔ i [cl]		*!*	
d. o o e <[cl]>	*!		*
e. u u i [cl] [cl]			***!*
f. ɔ u i [cl] [cl]		*!	**

The vowel [a] does not undergo harmony since the identity of place constraints outrank ALIGN[cl], as shown in Tableau 3.20.

Tableau 3.20

a i → a i	HEIGHTPL	IDENT[dor]	IDENT[cor]	ALIGN[cl]	IDENT[cl]
a. ☞ a i [cl]				*	
e i [cor] [cl]			*!		
o i [dor] [cl]		*!			
ə i [cl]	*!				

The optimal candidate in the tableau above violates ALIGN[cl], but satisfies the dominating constraints HEIGHTPL, IDENT[dor], and IDENT[cor].

3.1.12 Zulu

Zulu (Doke 1926, 1947; Harris 1987) is a Bantu language (S42) of the Nguni subgroup. Zulu has the vowel inventory specified in (3.61).

(3.61)

	i u	e o	ɛ ɔ	a
[closed]	•	•	•	
[closed]	•	•		
[closed]	•			

The vowels [ɛ ɔ] raise to [e o] when followed by a high vowel. This process is seen in (3.62), and mirrors low vowel raising in the Sotho and other Bantu languages. The data in (3.62.a) are from Harris (1987), and the data in (3.62.b) are from Doke (1926).

(3.62) Zulu raising.

a.	p^hɛk-a	'cook V'	um-p^hek-i	'cook N'
	ŋɛn-a	'enter'	ŋen-is-a	'bring-in'
	ɔn-a	'sin'	is-on-i	'sinner'
	bɔn-a	'see'	bon-is-a	'show'
b.	lɛ:lɔ	'that'	le:li	'this'
	ɛ:da	'finish'	siedi:lɛ	'we finished'
	nɛ:ndʒa	'and the dog'	ne:zi:mu	'and the cannibal'
	ɓɔ:na	'see'	siɓoni:lɛ	'we saw'
	khɔ:mmba	'point'	sikhommbi:lɛ	'we pointed'

Partial height harmony is described in terms of the alignment constraint in (3.63). The constraint prefers condidates in which an occurrence of [closed] is multiply linked between a vowel and a lower vowel to its left.

(3.63) Align([closed]$_{max}$, L, Word, L)—Zulu.

ALIGN[cl] = for all vowels specified for the maximum number of [closed], there exists one occurrence of [closed] for which the the left edge of that feature and the left edge of the word coincide.

ALIGN[cl] is highly ranked so that the optimal candidate is one in which IDENT[cl] is violated in order to satisfy (3.63). A candidate in which non-termial occurrence of [closed] is multiply linked fails, since such a candidate incs two IDENT[cl] violations. For example, candidate (b) incurs two IDENT[cl] violations, one for the occurrence of [closed] that must be aligned, and a second, fatal violation for its dependent. Candidate (a), in which terminal [closed] is multiply linked, incurs only one IDENT[cl] violation.

Tableau 3.21

bɔn-i → bon-i	MAX[cl]	ALIGN[cl]	IDENT[cl]
a. ☞ bon isa [cl]			*
b. bun isa [cl] [cl]			**!
c. bɔn isa		*!	
d. bɔn esa <[cl]>	*!		*

Candidate (c) in Tableau 3.21 is ruled-out since it violates ALIGN[cl]. Candidate (d) satisfies ALIGN[cl] vacuously by deleting an occurrence of [closed] from the high vowel in the suffix, thus incurring a MAX[cl] violation.

3.1.13 Tsonga

Tsonga (Baumbach 1974, Harris 1987) is a Bantu language (S53) spoken in Zimbabwe, Mozambique, and South Africa. Tsonga has the seven vowel system [i e ɛ a ɔ o u]. The examples in (3.64) show that Tsonga exhibits partial height harmony whereby the vowels /ɛ ɔ/ surface as [e o] when followed by a high vowel.[24]

[24] It is not clear from the relatively few polysyllabic roots provided by Baumbach whether harmony is iterative in Tsonga, or applies only in adjacent syllables as the form *ešihɛŋgeni* 'at the pineapple' suggests. If additional research reveals that harmony applies only locally, the fact that harmony applies only in adjacent syllables could be accounted for following Poletto's (1993, forthcoming) account of tone doubling in Olusamia. Poletto posits a constraint barring a singly linked H tone stem-finally, that is satisfied with a minimal violation of faithfulness when it is spread exactly once.

(3.64)

(3.64)	hɛl-a	'end'	hel-ili	'ended'
	šifiɛŋgɛ	'pineapple'	ešifieŋgeni	'at the pineapple'
			a-xi-hel-i	'it does not end'
	ndɛb-ɛ	'ear'	ndɛben-i	'at the ear'
	p^hɛh-a	'cook'	p^heh-ilɛ	'cooked'
	kɔk-a	'pull'	kok-ili	'pulled'
			kok-iw-a	'be pulled'
			kok-is-a	'let pull'
	hɔn-a	'sin'	ʃi-hon-i	'sinner'
	bɔn-a	'see'	bon-ilɛ	'saw'

The assimilation above is not a complete height harmony since the stem vowels in examples like /hɔn-i/ → [hon-i] do not assume the height of the trigger, but raise one step instead. Tsonga partial height harmony is described in terms of an assimilation of a single instance of the feature [closed], driven by an alignment constraint (3.65).

(3.65) Align([closed], L, Word, L)—Tsonga.

ALIGN[cl] = for all vowels specified for [closed], there exists one occurrence of [closed] for which the the left edge of that feature and the left edge of the word coincide.

Examples such as illustrate that partial height harmony in this language operates only when the target and trigger are in adjacent syllables.

Tableau 3.22 demonstrates the ranking of ALIGN[cl] relative to other constraints.

Tableau 3.22

hɔn-i → hon-i	MAX[cl]	ALIGN[cl]	IDENT[cl]
a. ☞ hon i [cl]			*
b. hun i [cl] [cl]			**!
c. o i		*!	
d. o e <[cl]>	*!		*

Since the vowel [a] does not participate in partial height harmony, the identity of place constraints are ranked above ALIGN[cl], as was seen for Servigliano Italian (3.24).

Tableau 3.23

	HEIGHTPL	IDENT[dor]	IDENT[cor]	ALIGN[cl]	IDENT[cl]
a. ☞ a i [cl]				*	
b. ε i [cl]			*!		*
c. ɔ i [cl]		*!			*
d. ə i [cl]	*!				*

Any candidate that satisfies ALIGN[cl] in Tableau 3.23 violates a higher ranked constraint and is ruled out.

3.1.14 Ejagham

Ejagham (Watters 1981) is an Ekoid Bantu language of the Cross-River region of Cameroon and Nigeria. Ejagham contrasts the vowels [i ε ʉ a ɔ u] underlyingly, but derives the vowels [e o] by a process of harmony. Partial height harmony in Ejagham raises the vowels [ε ɔ] one step before a high vowel, as seen in the examples in (3.66).

(3.66) Ejagham partial raising.

/ὲ-fân/	→	[ὲ-fân]	'we counted'	/ɔ̀-fân/	→	[ɔ̀-fân]	'you counted'
/ὲ-bú/	→	[è-bú]	'time'	/ɔ́-j!ɔ́/	→	[ɔ́-jɔ̌]	'tomorrow'
/ὲ-fin/	→	[è-fin]	'we closed'	/ɔ̀-fin/	→	[ò-fin]	'you closed'
/ὲ-kʉ̂/	→	[è-kʰʉ̂]	'funeral'	/ɔ̀-kún/	→	[ò-kʰúŋ]	'firewood'
/έ-fi/	→	[é-fi]	'boil (of body)'	/ɔ̀-čî /	→	[o-ç̬ʰî]	'face'

The alignment constraint active in Ejagham requires an occurrence of [closed] to be shared between a vowel and vowel to its left. Since the prohibition against vowels spreading [closed] to higher vowels is inviolable (2.3), the vowel [a] cannot trigger the process for any vowels, nor can mid vowels trigger the process for high vowels. In addition, IDENT[cor] and HEIGHTPL are ranked above ALIGN[cl] so that [a] cannot participate in the harmony.

(3.67) Align([closed], L, Word, L) — Ejagham.
ALIGN[cl] = for all vowels specified for [closed], there exists one occurrence of [closed] for which the the left edge of that feature and the left edge of the word coincide.

Tableau 3.24

ɔ-fin → o-fin	HEIGHTPL	IDENT[dor]	IDENT[cor]	ALIGN[cl]	IDENT[cl]
a. ☞ o fin [cl]					*
b. ɔ fin [cl]				*!	

The constraint ranking in Ejagham and illustrated in Tableau 3.24 achieves one-step raising for the mid vowels [ε ɔ] when followed by a high vowel.

3.1.15 Pulaar

Partial height harmony is also found in (Futa Toro) Pulaar (Paradis 1992), a dialect of Fula (a Niger-Congo language) spoken in Mauritania and northern Senegal. Harmony in Pulaar is seen in the examples below where the root vowel (underlined) is raised before a suffix containing a high vowel.

(3.68) Raising in Pulaar.

cɔf-ɔn	sof-ru	'chick'
cεr-kɔn	ser-du	'riflε butt'
mbεεl-ɔn	mbeel-u	'shadɔw'
pεεc-ɔn	peec-i	'slits'
mbεεl-ɔn	mbeel-i	'puddlεs'
dɔg-ɔ-w-ɔn	dog-oo-ru	'runnεr'
dɔg-ɔ-w-ɔn	loot-oo-ru	'washεr'

The root vowels in (3.68) raise one step before a high vowel in accordance with an alignment constraint that requires the multiple linking of [closed].

(3.69) Align([closed], R, Word, R)—Pulaar.
ALIGN[cl] = for all vowels specified for [closed], there exists one occurrence of [closed] for which the the right edge of that feature and the right edge of the word coincide.

Due to the Dominance/Precedence prohibition, the only possible multiple linking of [closed] involves a high vowel and a mid vowel so that ALIGN[cl] does not need to be restricted to vowels specified for the maximum number of occurrences of [closed].

Tableau 3.25

pɛɛc-i → peec-i	MAX[cl]	ALIGN[cl]	IDENT[cl]
a. ☞ ee i [cl]			*
b. ii i [cl] [cl]			**!
c. ɛɛ i [cl]		*!	
d. ɛɛ e <[cl]>	*!		*

The optimal candidate in Tableau 3.25 is that in which one, and only one, occurrence of [closed] is shared between a high vowel and a preceding vowel.

3.2 One-Step Raisings

The languages discussed in the previous section exhibit one-step raising triggered by a higher vowel. Some languages exhibit one-step raising that appears to be morphologically conditioned. In these languages, vowels in verb stems raise one step in particular tenses or aspects. The treatment of such phenomena varies widely, but they are analyzed here as involving an assimilation to an occurrence of [closed] that is morphologically affiliated. Whatever account of these languages is ultimately adopted, these languages bear out the predictions of the Incremental Constriction Model in that they all exhibit stepwise raising.

Describing an occurrence of [closed] as being morphologically affiliated suggests that it is not part of the lexical entry for the root nor a segment in some affix, but is introduced by the grammar to mark some morphological distinction. One might describe a tonal pattern that appears in a specific tense/aspect as morphologically affiliated since it marks a morphological distinction without being associated with any segmental material. Roberts (1994) provides examples of several "floating features" that act as morphemes from outside the tonal domain.

3.2.1 Basaá

Basaá (Schmidt 1994, Lemb and de Gastines 1973, Churma 1995) is a Bantu language (A44) spoken in Cameroon. Basaá has the vowels [i e ɛ a ɔ o u], which are specified in the Incremental Constriction Model as in (3.70) below. The specifications in (3.70) suggest that Basaá contrasts three heights, with the vowels [ɛ ɔ a] all specified for no degrees of [closed] so that these vowels form a single, lowest height. Schmidt (1994:2) specifies these vowels as [+low], but does so for comparative reasons. In fact, there is phonological evidence to support this claim, which will be discussed below.

(3.70) Basaá vowels.

	i	u	e	o	ɛ	ɔ	a
[coronal]	•		•		•		
[labial]		•		•		•	
[pharyngeal]							•
[closed]	•	•	•	•			
[closed]	•	•					

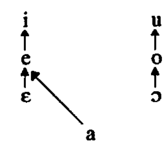
All the vowels below are found in most tenses, but in some tense/aspects, only the vowels [i e o u] appear. Schmidt (1994) acccounts for this distribution by a process that raises the vowels [e ɛ a ɔ o] one step. Raising occurs in the applied, passive, indirect causative, direct causative, simultaneous, reversive, and stative (Schmidt 1994:3). Schmidt characterizes the process as raising low vowels to mid, and mid vowels to high, assuming, as in (3.70), that [ɛ ɔ a] are all low. Raising in Basaá is seen in the examples in (3.71). The examples from the applied show that the root vowel is raised one step in the applied stem, and a process of complete vowel harmony determines the vowel of the applied suffix (the English glosses are provided by the current author). Raising does not apply to the indirect causative suffix, as the examples below indicate, but the root vowels are raised in this tense.

(3.71) Raising in Basaá.

stem	applied	ind. caus.	French gloss	English gloss
ɓak	ɓeg-el	ɓeg-ha	*tresser*	'weave'
pɛp	peb-el	peb-ha	*éventer*	'winnow'
hɛk	heg-el	heg-ha	*creer*	'believe'
yɔŋ	yoŋ-ol	yoŋ-ha	*prendre*	'take'
seŋ	siŋ-il	siŋ-ha	*frotter*	'rub, polish'
top	tub-ul	tub-ha	*chanter*	'sing'

Raising in Basaá is illustrated schematically below, adapted from Schmidt (1994:3). The fact that both [ɛ a] are realized as [e] in the raising environment demonstrates that these two vowels are of the same height.

(3.72) One-step raising in Basśá.



One-step raising in Basśá is accounted for by positing that an occurrence of [closed] is affiliated with the morphemes marking the applied, passive, indirect causative, direct causative, simultaneous, reversive, and stative. A constraint from the PARSE family (3.73) requires that the morphologically affiliated [closed] be linked to some vowel on the surface. Since low vowels may appear as suffixes in the raising context, e.g., *ɓeb-ha* 'cause to weave,' the morphologically affiliated [closed] is parsed to the root. Candidates that parse this occurrence of [closed] exclusively to the suffix are not optimal.

(3.73) Parse[closed].

PARSE[cl] = the feature [closed] must be linked to an element in the root in the output.

When the morphologically affiliated [closed] is associated to a vowel in the stem, that vowel raises one step, cf. (3.70). The vowel [a], which lacks a place feature, acquires a specification for [coronal] to satisfy HEIGHTPL.

Tableau 3.26

ɓag-ha → ɓeg-ha	PARSE[cl]	IDENT[dor]	IDENT[cor]	IDENT[cl]
a. ☞ ɓeg ha [cor] [cl]			*	*
b. ɓag he [cor] [cl]	*!		*	*
c. ɓɔg ha [dor] [cl]		*!		*
ɓag ha	*!			

Tableau 3.27

yɔŋ-ol → yoŋ-ol	PARSE[cl]	IDENT[dor]	IDENT[cor]	IDENT[cl]
a. ☞ yoŋ ol [cl]				*
b. yɔŋ ol [cl]	*!			
c. yeŋ ol <[dor]> [cor] [cl]		*!	*	*

The high vowels do not raise. This is attributed to a structure preserving constraint that prohibits a vowel from acquiring more occurrences of [closed] than are active in the language. A language knows what segments are in its iventory, as well as the features required to contrast them. Thus, a language with three vowel heights knows that the vowels [i u] are specified for two occurrences of [closed] and that no other vowel is specified for more occurrences of [closed] than are [i u]. A language knows what $[\text{closed}]_{max}$ is through comparison of its inventory. In language with three heights, two is the maximum number of [closed], though the language does not need to count to determine what $[\text{closed}]_{max}$ is.

(3.74) *>MAX.

*>MAX = a vowel can be specified for no more than the maximum number of occurrences of [closed] active in the language.

*>MAX is ranked higher than PARSE[cl].[25] Candidate (c) in Tableau 3.28 demonstrates that leaving the morphologically affiliated [closed] completely unparsed is better than parsing it to the suffix.

Tableau 3.28

	*>MAX	PARSE[cl]	IDENT[cl]
a. ☞ i ol [cl]		*	
b. i ol [cl]	*		
c. i ul [cl]		*	*!

The ranking in (3.75) derives the correct outputs for Basaá.

(3.75)

*>MAX » PARSE[cl], IDENT[dor] » IDENT[cor], IDENT[cl]

Though not a strict assimilation, morphologically conditioned raising in Basaá is consistent with the predictions (2.8) of this model: Basaá raising involves raising, and it involves a single step shift. The behavior of the vowel [a], which raises to [e], indicates that the vowels [ɛ a ɔ] constitute a single height in Basaá. Raising in this language is accounted for by positing that a morphologically affiliated occurrence of [closed] is part of the input for certain tense/aspects. The constraint PARSE[cl] requires that [closed] be parsed to the root of a verb in this context, thereby raising it one step.

3.2.2 Gbanu

Stepwise raising is also found in the Niger-Congo language Gbanu (Monino 1990; Bradshaw 1995, 1996), spoken in the Central African Republic. Gbanu contrasts the seven vowels [i e ɛ a ɔ o u]. All of these vowels are found in the imperfective, while in the perfective, the vowels [ɛ ɔ] do not appear. Bradshaw accounts for this by positing a process by which the vowels /ɛ ɔ e o/ are raised one step to [e o i u], respectively. Since /ɛ ɔ/ are raised in the perfective, these vowels never surface as such in this tense. The high vowels and the low vowel [a] do not alternate, as seen below.

[25] The constraint *>MAX does not appear to be violated by any language so that this constraint may be better understood as a universal prohibition on GEN rather than a rankable constraint.

(3.76) Gbanu raising.

imperfective		perfective	
zɛkɛ	'sift'	ze̱kɛ	'has sifted'
hɛlɛ	'tie'	he̱lɛ	'has tied'
pɛ	'seed'	pe̱ɛ	'has seeded'
gɔmɔ	'chop'	go̱mɔ	'has chopped'
ɲɔŋɔ	'eat'	ɲo̱ŋɔ	'has eaten'
kɔ̃	'want'	kõ̱ɔ̃	'has wanted'
zele	'hear'	zi̱le	'has heard'
hele	'cry'	hi̱le	'has cried'
ʔe	'put'	ʔi̱e	'has put'
tombo	'send'	tu̱mbo	'has sent'
dolo	'forge'	du̱lo	'has forged'
k͡po	'knot'	k͡pu̱o	'has knotted'

In the case of stems which surface as disyllabic in the imperfective, it appears that the perfective can be predicted from this form by simply raising the first vowel (V1) one step. Bradshaw (1996) argues that such an analysis misses an important generalization, namely, that the second vowel (V2) of disyllabic stems is always an exact duplicate of V1. Bradshaw argues that V2 is inserted for all disyllabic stems in the imperfective (as those stems are monosyllabic CVC underlyingly). The quality of V2 is identical to V1 because the two share structure. The epenthesis of V2 is motivated to avoid a coda (this constraint takes the form of *CODA in Prince and Smolensky 1993).

Those stems which are monosyllabic in the imperfective, i.e., CV, surface as bimoraic CVV in the perfective. Again, V2 for these stems is identical to V1. Bradshaw (1996:4) analyzes V2 in CVV perfectives as a mora introduced as part of the perfective morphology, i.e., the extra mora is morphologically affiliated.[26] The "perfective" mora is attached to both CV and CVC roots so that they surface as CVV and CVCV repectively (*CODA is thus satisfied). In both types of roots, multiple linking of all vowel features ensures the identity of V1 and V2.

The one-step raising of the perfective is attributed to a morphologically affiliated occurrence of [closed]. This feature links to V1, raising it one step. As for Basaá, PARSE[cl] requires the morphologically affiliated [closed] to be associated to the root, in this case to the left edge of the root.

Bradshaw (1996:7–9) notes that V1 and V2 must undergo a process of cloning (Hume 1994) whereby two multiply linked vowels separate. This is necessary since only one of the two moras raisies in the perfective, cf. *zekɛ* 'has sifted' and *k͡puo* 'has knotted.' Cloning will be referred to again in the analysis of diphthongization.

[26]The additional mora present in the perfective of CV stems might also be attributed to epenthesis as well, in this case to meet a constraint that requires pefectives to form a metrical foot. No part of this analysis depends on selecting one analysis over the other.

Tableau 3.29

zɛkɛ → zekɛ	HEIGHTPL	IDENT[dor]	IDENT[cor]	PARSE[cl]	IDENT[cl]
a. ☞ z e k ɛ [cl]					*
b. z ɛ k ɛ <[cl]>				*!	

As HEIGHTPL and the identity of place constraints are ranked above PARSE[cl], the low vowel can undergo raising.

Tableau 3.30

hana → hana	HEIGHTPL	IDENT[dor]	IDENT[cor]	PARSE[cl]	IDENT[cl]
a. ☞ hana <[cl]>				*	
b. hɛna [cor] [cl]			*!		*
c. hɔna [cor] [cl]		*!			*
d. həna [cl]	*!				*

Following the analysis in Bradshaw (1995, 1996), morphological raising in Gbanu receives a straightforward treatment within the Incremental Constriction Model. The morphology inserts a specification of [closed], and that feature raises the vowel to which it is linked one step. Raising in Gbanu is consistent with the predictions of the Incremental Constriction Model.

3.2.3 Imonda

Imonda (Seiler 1985) is a Papauan language spoken in New Guinea that exhibits stepwise raising. Imonda has the vowels in (3.77).

(3.77) Imonda vowels.

i	ɨ ʉ	u
e	ə	o
ɛ		ɔ
æ	a	ɒ

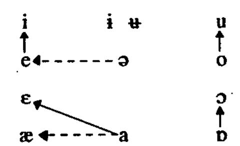
In Imonda, plurality may be marked on a verb stem by raising the final stem vowel one step (Seiler 1985:16-17, 82), as seen in the examples below, or by fronting when the final stem vowel is central.

(3.78) Imonda raising/fronting.

se	→	si	'cut'
fe	→	fi	'make, do'
pos	→	pus	'dig'
la	→	læ	'light fire'
sah	→	sæh	'call
sah	→	sɛh	'search'
nagla	→	naglɛ	'see'
tas	→	tɛs	'clean'
ɒ	→	ɔ	'say'
lɒl	→	lɔl	'talk, say'
kulɒ	→	kulɔ	'roll up'
sə	→	si	'wash after birth'
nəl	→	nil	'pick fruit'
səh	→	sih	'search'

The vowels [e o ɒ] raise one step (depicted by the solid arrows) to mark the plural while the central vowels [a] and [ə] front (depicted as dashed arrows). And in some cases, the vowel [a] fronts and raises to [ɛ].

(3.79) Fronting and raising in Imonda.



The words *sah* 'call' and *sah* 'search,' which have the plural forms *sæh* and *sɛh*, indicate that the vowels of these two stems are distinct phonologically. This phonological distinction is realized in the plural forms where one instance of [a] is fronted to [æ] and the other is fronted and raised to [e]. Since 'call' and 'search' are identical in the singular, [sah], but distinct in the plural, [sæh] 'calls'—[sɛh] 'searches,' this suggests that each root has a different vowel, but that the contrast is neutralized in the singular. The vowels [a] and [æ] are contrastive, as the minimal pair *mal* 'scar' and *mæl* 'river bank' illustrates. The vowels [æ ɛ ɔ] only appear in final position as a result of raising (Seiler 1985:17) so that these vowels have no raised counterparts.

However the phonological distinction between the two *a*'s in Imonda is realized; the plural formation illustrated in (3.78) can be described as a process that fronts central vowels, and raises perpheral vowels (as well as one of the two *a*'s). Of interest here is the process of raising.

(3.80)

	high				*mid-hi*		*mid-lo*			*low*		
	i	ɨ	ʉ	u	e	o	ɛ	ə	ɔ	æ	a	ɒ
[coronal]	•				•		•			•		
[labial]			•	•		•			•			•
[doral]				•		•						•
[closed]	•	•	•	•	•	•	•	•	•			
[closed]	•	•	•	•	•	•						
[closed]	•	•	•	•								

The morphology of Imonda introduces an occurrence of [closed] to mark the plural. The constraint PARSE[cl] ensures that the morphologically affiliated occurrence of [closed] is associated to the stem-final vowel in the output.

Tableau 3.31

se → si	PARSE[cl]	IDENT[cl]
a. ☞ si | [cl]		*
b. se <[cl]>	*!	

The raising seen in Imonda can be characterized in terms of a single feature, [closed], where a vowel that undergoes raising to form the plural acquires an occurrence of the feature [closed] from the morphology and thereby surfaces as one step higher.

3.3 Issues Surrounding Height Assimilation

In this section, some issues concerning the description of vowel height assimilation are addressed. First, a reanalysis of some of the languages discussed in the previous sections based on the feature [ATR], in place of [closed], is considered. Next, the mechanics of deriving a new height in the Incremental Constriction Model is examined. The status of the corroborative evidence of diachronic chain shifts is discussed. The Incremental Constriction Model is compared to alternative treatments of height assimilation. Finally, some languages that look like counterexamples are addressed.

3.3.1 [ATR] versus [closed]

Many of the languages discussed above exhibit assimilations in which the vowels [ɛ ɔ] move to [e o] before [i u]. For example, in Pulaar, §3.1.15, the vowel of the stem alternates in accordance with the suffix vowel as in *mbɛɛl-ɔn* but *mbeel-u* 'shadow.' This alternation (and others like it) is analyzed here in terms of the feature [closed]. Elsewhere, these alternations may have been described in terms of the feature [ATR]. Pulaar, for example, is analyzed by Paradis (1992) as an [ATR] harmony in which the high vowels [i u] spread [+ATR] onto the preceding [−ATR] vowel.

An immediate question to be answered concerns the status of the feature [ATR] in the Incremental Constriction Model. It is argued here that the feature [ATR] (or its equivalent, e.g., [pharyngeal]) is needed in addition to [closed].[27] The use of [ATR], however, should

[27] The status of [tense] is unclear. It may be possible to analyze many tense/lax alternations in terms of

be strictly limited to cases in which languages exhibit cross-height harmony, such as Akan (Stewart 1967, Lindau 1975, and others) or Kɔnni (Cahill 1996a). Kɔnni has the vowels [i ɪ e ɛ a ɔ o ʊ u]. These vowels are divided into two sets—[i e o u] and [ɪ ɛ a ɔ ʊ]—where stems tend to contain vowels exclusively of one set or the other. Cahill (1996a) analyzes the distribution of vowels in Kɔnni as a harmony for the feature [ATR] which spreads from a root vowel throughout the stem.

It is possible to analyze the Pulaar facts as an assimilation of [ATR] in which the high vowels [i u] spread their [ATR] value onto /ɛ ɔ/. As an [ATR] analysis is possible for Pulaar, the question is raised as to whether the [closed] analysis is necessary, or even an improvement over the traditional [ATR] analysis. For some languages, the [closed] analysis is indeed an improvement over the [ATR] alternative because the latter is not adequate to describe the phenomenon. In Sesotho (and the other Sotho languages), [ATR] cannot describe the facts. Recall from §3.1.6 that the process *ɛ ɔ → e o* is triggered by [ɪ ʊ] as well as by [i u]. Thus, all of the vowels [i ɪ ʊ u] require a [+ATR] specification in order to trigger the change, e.g., /bɔn-ɪ/ → *bonɪ* 'not see.' However, the vowels [ɪ ʊ] must be specified as [–ATR] since these vowels also undergo the assimilation to surface as [i u], e.g., /lɪm-i̧/ → *limi̧* 'farmer.'

For other langauges, characterizing the *ɛ ɔ → e o* alternation in terms of [ATR] misses a generalization. In Nzebi (§3.1.5), for example, the same process that raises the mid vowels also raises [a] to [ɛ], a change that cannot be described in terms of [ATR]. In order to correctly characterize the whole pattern found in Nzɛbi, [ATR] must be abandoned in place of another feature which characterizes vowel height as a single dimension. Schmidt (1994) describes Basaá vowel raising in terms of [ATR], but such an analysis requires a much more complicated analysis including repair strategies and neutralization that are unnecessary in the analysis offered in §3.2.1.

In contrast, there is strong evidence in favor of the [ATR] analysis in languages such as Akan (Lindau 1975, Stewart 1967). In Akan, any vowel of the [+atr] set may trigger the changes /ɛ ɔ/→[e o] or /ɪ ʊ/→[i u]. In (3.81), the prefix vowel /ɪ/ becomes [i] before [o]. Stewart (1967) argues that this assimilation cannot be described in terms of height since the output [i] is *less* similar to [o] in terms of height than [ɪ] is. Only an account based on tongue root position (or pharyngeal volume) allows the /ɪ/ → [i] change to be described as an assimilation (since [i] and [o] both have advanced tongue roots relative to [ɪ]).

(3.81) [ATR] harmony in Akan.

mi̠-ko-tu	'I go'
mɪ̠-kɔ-tʊ	'I pull out'

Languages such as Sesotho allow the vowels /ɪ ʊ/ to become [i u] only before higher vowels. This process is never triggered by a mid vowel. The failure of mid vowels to trigger the alternation in Sesotho is explained if this constitutes a height assimilation.

Pulaar has a smaller inventory than does Akan (3.82), thus the alternation /ɪ ʊ/ → [i u] / __ e o cannot be found. Therefore, this clear diagnostic is not available to differentiate the "height" ([closed]) from the "tongue root" ([ATR]) analyses.

(3.82)

Akan			Pulaar		
i		u	i		u
ɪ		ʊ			
e		o	e		o
ɛ		ɔ	ɛ		ɔ
	a			a	

[closed], though further research is necessary. Describing the tense/lax contrast in English, for example, in terms of [closed] misses some generalizations, such as the fact that the lax vowels [ɪ ʊ ɛ ɔ] never appear in word-final open syllables. It may be possible, however, to analyze such facts in terms of length rather than tenseness. This question is left to future investigation.

Often, the distribution of [e o] is limited so that [+ATR] suffixes are not attested, and therefore cannot trigger the harmony, even for mid vowels. This points to a need for another, reliable diagnostic for determining that a given system exhibits [ATR] harmony. Only an examination of a large number of cases of [ATR] assimilation will reveal reliable diagnostics for distinguishing true [ATR] assimilations from height based systems (i.e., languages where the [ɛ]/[e] contrast is based on [ATR] and those where the [ɛ]/[e] contrast is based on [closed]). Until such diagnostics are developed, however, it will remain uncertain which analysis of Pulaar is appropriate. The existance of languages such as Sesotho, Nzebi, Gbanu, etc., establishes the need inadequacy of [ATR] for some languages and the need for a description of these languages using [closed] as in the Incremental Constriction Model.

3.3.2 Derived heights

This section addresses the treatment of derived heights within the Incremental Constriction Model. Partial height harmony in Kikuria raises all non-high vowels of this language one step. All vowels that have undergone harmony are found outside the raising environment. That is, [e o] are all phonemic in Kikuria. In contrast, partial height harmony in Gitonga derives vowels that are not found outside the raising environment. That is, [e o] are strictly derived.

(3.83)

Kikuria			Gitonga		
ɛ	→	e	ɛ	→	e
ɔ	→	o	ɔ	→	o

In §3.1.11, the Gitonga surface vowel inventory was specified as in (3.84.a) in which the high vowels are specified for three occurrences of [closed]. However, if only the underlying inventory is considered, then Gitonga vowels are specifed as in (3.84.b). The issue that derived heights in languages such as Gitonga raises is how to reconcile the phonemic and surface specifications.

(3.84) a. *surface*

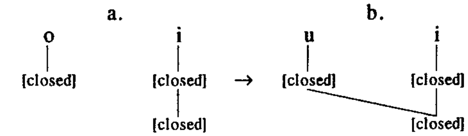
	i u	e o	ɛ ɔ	a
[closed]	•	•	•	
[closed]	•	•		
[closed]	•			

b. *underlying*

	i u	ɛ ɔ	a
[closed]	•	•	
[closed]	•		

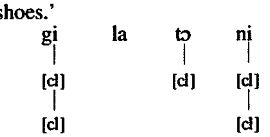
Assuming the specifications in (3.84.b), the assimilation in which a single instance of [closed] is spread will incorrectly raise the target vowel to a high vowel (3.85).

(3.85) a. b.



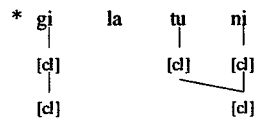
Derived heights are treated the Incremental Constriction Model is as follows. Gitonga vowels are specified as in (3.84.b), with two occurrences of [closed] contrasting the three heights in the underlying inventory. These specifications are the input to the phonology for forms such as /gilatɔ-ni/ (3.86). As GEN nominates an exhaustive set of candidates to be evaluated, a number of candidates in which an occurrence of [closed] in the suffix is multiply linked with the preceding vowel are produced. (These candidates are favored by the constraint ALIGN[cl].)

(3.86) Input to *gilatoni* 'in shoes.'



Among these multiply linked candidates is one in which an occurrence of [closed] is multiply linked with the preceding vowel, raising it to a high vowel (cf. the feature specifications in (3.84.b)). This candidate is depicted in (3.87).

(3.87) /ɔ/ is raised to *u*.



While this candidate satisfies ALIGN[cl], it violates another constraint that requires that contrasts be maintained. This constraint, PRESERVECONTRAST, prohibits neutralization.[28] A language knows what sounds are in its inventory, and thus the contrasts within that inventory. The grammar of Gitonga knows that there is a contrast between the height of the stem vowel [ɔ] in the stem *gilatɔ* 'shoes' and the vowel [i] of the locative suffix *-ni* (one of them is specified for the same number of occurrences of [closed] as is [u], and the other has fewer). The constraint in (3.88) seeks to preserve that height contrast.

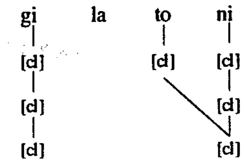
(3.88) Preserve contrast.

PRESERVECONTRASTHEIGHT = don't neutralize height contrasts.

PRESERVECONTRAST is violated by (3.87) since the mid vowel /ɔ/ in the input is no longer contrastive with [u] in terms of height (i.e., each vowel has the same number of instances of [closed]). PRESERVECONTRAST is satisfied by a candidate produced by GEN in which an occurrence of [closed] is inserted on all high vowels (i.e., high in the input) and multiply links an occurrence of [closed] to the preceding mid vowel to derive a new vowel that is higher than its input correspondent, but not the same height as the high vowels in Gitonga.

[28] The PRESERVECONTRAST constraint is probably relevant for other oppositions than vowel height. The notion of preserving contrast is persued by other authors (e.g., Homer 1996).

(3.89) *gilatoni.*



The candiadate in (3.89) violates some faithfulness constraints since occurrences of [closed] are inserted to the high vowels, but the high ranking ALIGN[cl] and PreserveContrast are satisfied, making (3.89) optimal. In essence, the drive of PRESERVECONTRAST is to allow the non-distinctive vowels [ɛ] and [e] differ while both of these realizations of the phoneme /ɛ/ contrast with [i]. The grammar of Gitonga knows that [i] contrasts with both surface manifestations of /ɛ/, and furthermore, that [e] and [ɛ] differ by height as well. The definition of [closed] (§2.1.1) dictates that [i] will have the most occurrences of [closed], and that [e] will have more occurrences of [closed] than [ɛ].

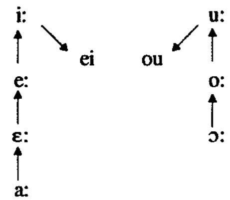
The solution provided here for derived height in Gitonga can be extended to the derived heights in Tsonga, Zulu, Ejagham, and Pulaar. Note that the vowels [e o] are not derived in all languages in which partial height harmony raises /ɛɔ/ to [e o], such as Kikuria and Servigliano, where [e o] are contrastive. In Sesotho, Setswana, and Northern Sotho, the vowels [ɛ ɔ] and [e o] contrast while partial height harmony raises /ɛ ɔ/ to [e o]. In these languages, however, the same process of assimilation also derives a new height when /ɪ ʊ/ surface as [i u] as a result of partial height harmony. In all cases of derived height through assimilation, the new height is always one step below the highest vowels, i.e., the neutralization avoided by deriving a new height would have involved the highest vowels.

3.3.3 Chain Shifts

All of the examples discussed in the preceeding sections involved synchronic vowel shifts in which one or more vowels move along the height continuum. Among these languages, there are several in which vowels of more than one height move simultaneously. This set of chain shifts comprises Lena Spanish, Servigliano Italian, Nzɛbi, Sesotho, Setswana, Northern Sotho, Basaá, Gbanu, and Imonda, where the last three are morphologically conditioned. All cases of synchronic chain shifts are consistent with the predictions of the Incremental Constriction Model. All such shifts involve raising, and all involve a one step change.

This leaves open the question as to whether diachronic chain shifts are also consistent with these predictions. Preliminary results suggest they are. Labov (1994:115–154) observes a number of generalizations that hold for chain shifts (see also Donegan 1978, Labov et. al. 1972, Wanner 1985 and references therein). Among Labov's generalizations is *principle I*: in chain shifts, long vowels raise (Labov 1994:116). Labov goes on to provide numerous examples bearing out this principle, establishing it as a robust generalization among diachronic chain shifts. One such example is the Great Vowel Shift (e.g., Jespersen 1909:231–47) which affected all long vowels between Middle and Modern English. The Great Vowel Shift raised all vowels one step, except for the high vowels, which diphthongized to [ei] and [ou] (later [ai] and [au]) (Jespersen 1909:231).

(3.90) The Great Vowel Shift.



While analyses of the Great Vowel Shift vary from author to author, the basic facts are consistent with the predictions of the Incremental Constriction Model. Vowels undergo one-step raising.

Labov also notes *principle II*, which states that short vowels fall. This principle appears to contradict the one-step raising prediciton of the Incremental Constriction Model, though it is important to realize that such lowering is apparently motivated by the need to make room in the perceptual space of a vowel system. Both cases of lowering cited in Labov (1994) involve the falling of short vowels accompanied by raising long vowels—short vowels fall only where long vowels rise. *Principle I* is far more robust than *principle II*, and there does not appear to be an obvious phonetic explanation for why chain shifts involve raising but never lowering (in the absence of concomitant raising). While the predictions of the Incremental Constriction Model are exceptionless in synchronic phonology, these predictions are robustly attested in diachronic phonology with only a restricted number of phonetically explained exceptions. Thus, the Incremental Constriction Model correctly captures a generalization that is true of diachronic sound change, namely, *principle I*.

3.3.4 Alternative Analyses

As argued above (§2.3, §3.1.5), approaches to vowel height that characterize vowel height with unrelated features fail to provide a unified account of languages such as Lena Spanish, Servigliano Italian, Nzɛbi, Sesotho, Kikuria, Gbanu, Basaá, and Imonda in which vowels of more than one height raise one step simultaneously. Such accounts cannot treat the related changes as a whole since each "step" requires reference to a different feature. For, example, the Nzɛbi changes make reference to three different features in an account employing [high], [low], and [ATR].

(3.91) One-Step raising in Nzɛbi.

a	→	ɛ	[+low]	→	[–low]
ɛ ɔ	→	e o	[–ATR]	→	[+ATR]
e o	→	i u	[–high]	→	[+high]

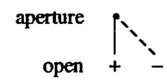
While such facts are problematic for multiple-feature models, there are other incremental approaches that are able to characterize languages such as Nzɛbi. Clements (1991), for example, provides an account of Nzɛbi using multiple values of the binary feature [±open]. In this approach, Nzɛbi vowels are specified as in (3.92).

(3.92) Nzɛbi vowels using [open].

	iu	eo	ɛɔ	a
$[\text{open}]_1$	–	–	–	+
$[\text{open}]_2$	–	–	+	+
$[\text{open}]_3$	–	+	+	+

Using the feature [open], Nzɛbi raising is analyzed as an assimilation for an occurrence of [–open]. As spreading $[\text{–open}]_3$ is distinct phonologically from spreading $[\text{–open}]_2$, the rule is formalized as in (3.93) to capture the One-step nature of the process.

(3.93) Nzɛbi raising using [open].



This rule states that the feature [–open] spreads to a preceding aperture (Height in the Incremental Constriction Model) node. The degree of closed that spreads is determined by the target where the phonology looks for the tier on which a '+' - '–' sequence appears.

There are a number of differences between the approach in Clements (1991) and the Incremental Constriction Model. First, the tier on which an occurrence of [open] resides is significant whereas each instance of [closed] is indistinguishable from all other occurrences of that feature in the Incremental Constriction Model. The model in Clements (1989, 1991) allows for a greater number of types of assimilation. For example, given the specifications in (3.92), if [i] were to spread $[\text{–open}]_2$ (instead of $[\text{–open}]_1$) to [a], then this vowel would surface as [e]. Since two-step raisings are unattested, this is considered a bad result. (Recall that the interaction of alignment constraints with IDEN[cl] ensures that one-step raisings are always better candidates than two-step raisings.)

A second problem for the [±open] approach is that this feature is binary (cf. §2.1.3), so that both values are predicted to spread, delink, etc., cross-linguistically. Since partial lowering is unattested in the world's languages, an approach using binary features misses the generalization that no languages spread [+open].

Another approach to one-step raising is found in Kirchner (1996), who provides an optimality theoretic account of Nzɛbi (cf. §3.1.5 and this section). Raising, in his analysis, is accounted for by positing the constraint RAISING (3.94) in Kirchner (1996:344). RAISING is satisfied to the degree that a vowel becomes high. Note, however, that a language does not have direct access to how high a vowel's height relative to the highest vowels based on the features [high], [low], and [ATR]. In addition, RAISING violations are counted in terms of "steps" so that the vowel [e] is one step below high and therefore incurs one violation of Raising while [ɛ] is two steps from high and therefore incurs two violations of RAISING. That is, Kirchner's approach requires vowel height to be conceptualized as a single phonetic scale (contra his use of features) and is evaluated in terms of steps along that scale (similar to using instances of [closed]).

RAISING is sensitive to morphology since yotization is found only in the Recent Past (affirmative and negative), the Today Past, and the Immediate Past (Guthrie 1968:105-7).

(3.94) **RAISING**

Maximize vowel height (in verbs when occurring with certain tense and aspect affixes).

Mitigating against the complete satisfaction of RAISING (which unchecked would raise all vowels to [i] or [u]) are the faithfulness constraints in (3.95), requiring the faithful parsing of the height features [high], [low], and [ATR] (Kircher 1996). These constraints are satisfied when an output vowel "preserves" the feature specification of the input vowel.

(3.95) **PARSE [low]**

If [low] is specified α in the input, it is specified α in the output.

(3.96) **PARSE [ATR]**

If [ATR] is specified α in the input, it is specified α in the output.

(3.97) **PARSE [high]**

If [high] is specified α in the input, it is specified α in the output.

Kirchner (1996) then establishes a disjunction relation for pairs of the PARSE constraints, so that the disjoined constraints are satisfied if at least one of the two is satisfied. The desired effect of disjoining the PARSE constraints is to "constrain the 'distance'" along the height continuum between input and output forms (Kirchner 1996:341). The constraint PARSE[low]∨[ATR] (3.98.a) is satisfied if a vowel preserves its specification of [low] but changes its [ATR] specification, or if a vowels changes its specification for [low] but preserves its [ATR] specification.

(3.98) **PARSE[low] ∨ PARSE[ATR]**

The output must have an identical specification as its input correspondent for either [low] or [ATR].

(3.99) **PARSE[high] ∨ PARSE[ATR]**

The output must have an identical specification as its input correspondent for either [high] or [ATR].

These two constraints are not ranked with respect to each other, but both are ranked above RAISING as the tableaux from Kirchner (1996) demonstrate. In Tableau 3.32.a, the first two candidates satisfy both PARSE constraints, but the second candidate incurs fewer violations of RAISING, and is therefore optimal. The third and fourth candidates violate at least one of the disjoined constraints (3.98) and (3.99), and are ruled out. (For the disjoined constraints below, an '*' denotes that this constraint is violated, i.e., both features are altered. When only one feature in the disjunction is altered, that feature is noted, but the constraint is satisfied. If neither feature is altered, no mark appears in the tableau.)

Tableau 3.32

		[low] or [ATR]	[high] or [ATR]	RAISING
a.	a → a			***!
☞	a → ε	+ → – [low]		**
	a → e	*!	– → + [ATR]	*
	a → i	*!	*	
b.	ε → a	– → + [low]		**!*
	ε → ε			**!
☞	ε → e	– → + [ATR]	– → + [ATR]	*
	ε → i	– → + [ATR]	*!	
c.	e → a	*!	+ → – [ATR]	***
	e → ε	+ → – [ATR]	+ → – [ATR]	**
	e → e			*!
☞	e → i		– → + [high]	
d.	i → a	*!	*	***
	i → ε	+ → – [ATR]	*!	**
	i → e		+ → – [high]	*!
☞	i → i			

Kirchner's analysis accounts for the Nzεbi facts, correctly deriving one-step changes for all non-high vowels. Kirchner (1996:344) states that his account of Nzεbi is "a general phonological solution, albeit one involving a morphologically conditioned constraint." The RAISING constraint in (3.94), however, does not refer to any phonological[29] properties. Nor is his treatment of this phenomenon generalizable to other languages displaying similar shifts, as demonstrated below.

The facts of Sesotho are problematic for Kirchner's approach as well, since the constraints and ranking posited for Nzεbi select the wrong candidate in Sesotho in Tableau 3.33. Notice that the optimal candidate is *two* steps higher in the output than in the input (where ☛ marks the unattested, but optimal form and ? indicates the correct output).

[29] Kirchner (1996:344) argues against analyzing Nzεbi Rasising as an assimilation based, in part, on the fact that "the suffix *-i* in the raised form is omitted except in extremely careful speech." The appearence of V_2, in and out of the raising context, is determined by speech rate, and is an orthogonal issue. Kirchner further argues against "a general phonological process of vowel raising before a high vowel," offering the example *banix* 'oranges.' In fact, *banix* is a dimorphemic noun where *ba-* is a noun class prefix. Guthrie describes yotization in terms of verb bases, and tenitively suggests yotization may be active in noun roots, in which case prefixes are excluded from the process (1968:118-19). Kirchner has not, therefore, successfully argued against an assimilatory account.

Tableau 3.33

ε → e	[low] or [ATR]	[high] or [ATR]	RAISING
a. ε → a	– → + [low]		*!***
b. ε → ε			*!**
c. ? ε → e	– → + [ATR]	– → + [ATR]	*!*
d. ☛ ε → ɪ		– → + [ATR]	*
e. ε → i	*!	*	

Thus, while Nzεbi and Setswana both exhibit one-step vowels shifts, Kirchner must posit different accounts for the two languages. That Kirchner's analysis of Nzεbi cannot account for the Setswana facts is a more serious problem than it appears at first glance. While his account correctly captures the one-step raising effect found in Nzεbi, Tableau 3.33 demonstrates that his analysis predicts two-step raising to exist. As demonstrated in both the synchronic cases examined here and the diachronic cases discussed elsewhere, partial lowerings are unattested.

While Kirchner (1996) and Clements (1991) provide accounts of Nzεbi, these approaches fail to rule out two-step raising, and partial lowerings. These models, therefore, miss the generalization that all partial height assimilations are one-step raisings. In addition, Kirchner's account of Nzεbi cannot be extended to other languages that exhibit similar alternations. Only the Incremental Constriction Model accounts for all cases of partial harmony while correctly predicting unattested phenomena not to exist among the world's languages.

3.4 Summary

This chapter has presented 18 languages that exhibit (synchronic) one-step raising. Some cases of one-step raising are assimilatory, in which the triggering vowels is always higher than the harmonizing vowel. Other cases of one-step raising are morphologically triggered. The Incremental Constriction Model provides an elegant account of all such languages in terms of the feature [closed], where the vowel that raises acquires a single instance of this feature. An comparison of the Incremental Constriction Model to other approaches to the phenomenon of one-step raising demonstrates that the analysis proposed here uniquely captures the generalization that all such shifts involve raising a vowel one step.

CHAPTER 4

FURTHER ISSUES IN THE REPRESENTATION OF VOWEL HEIGHT

4.0 Introduction

In Chapter 3, the Incremental Constriction Model was implemented in the account of several languages which exhibit partial height harmony. These languages provided strong support for this model because they bear out the prediction made by the Incremental Constriction Model that all partial height harmonies are one-step raisings. In this chapter, other vowel alternations that involve vowel height are discussed. In addition, a number of issues that bear on the representation of vowel height are addressed. This chapter begins, in §4.1, with an examination of vocalic phenomena that involve height, including complete height harmony, coalescence, and diphthongization. The Incremental Constriction Model is shown to provide an adequate treatment of all of these phenomena. In §4.2, "low" vowels are examined cross-linguistically. While some authors (e.g., Goad 1993) state that [ε ɔ] are "low" vowels, other authors reject an analysis of these vowel systems in that way (Churma 1995). Here, it is suggested that some languages may divide up even similar vowels spaces into different phonological categories. In §4.3, the interaction of vowel place features with vowel height is addressed.

4.1 Other Height Related Phenomena

The previous chapters examined partial height harmony and its implications for the representation of vowel height. In this section, other vocalic phenomena that also involve vowel height are discussed. This section begins with a survey of complete height harmonies §4.1.1. Vowel coalescence is addressed in §4.1.2, and diphthongization is discussed in §4.1.3. An account of each of these phenomena is presented within the Incremental Constriction Model of vowel height.

4.1.1 Complete Height Harmony

Complete height harmony differs from partial height harmony in its effect, how it is characterized, and the degree to which contrasts are maintained. While partial height harmony moves a target vowel part way toward a trigger with respect to height, complete height harmony moves the target to the exact height of the trigger. Thus, the target emerges with a height intermediate to its own and that of the trigger in partial height harmony but with the same height as the trigger in complete height harmony.

Partial height harmony is expressed as an assimilation for a single height feature. In the Incremental Constriction Model, this is the feature [closed]. Complete height harmony is expressed as an assimilation for all height features. Partial height harmony, as seen in Chapter 3, is described in terms of an alignment constraint requiring the multiple linking of [closed]. Complete height harmony is described below in terms of an alignment constraint that refers to all height features requiring the multiple linking of the Height node (in the Incremental Constriction Model).

Complete height harmony will be shown to eliminate height contrasts, while partial height harmony preserves these contrasts to a greater extent. In an assimilation in which the target emerges at the same height as the trigger, its underlying height is unrecoverable. Thus, in an assimilating context, harmonizing vowels cannot contrast for height, only for place. In partial height harmony, on the other hand, the underlying height of a target vowel is usually recoverable (i.e., it is one step lower underlyingly than it is when raised) so that harmonizing vowels may still contrast for height.

4.1.1.1 Kimatuumbi

Kimatuumbi (Odden 1991, 1996; §2.4.3) contrasts the vowels in (4.1).

(4.1) Kimatuumbi vowels.

i		u
ɪ		ʊ
ɛ		ɔ
	a	

While all of these vowels are found stem-initially, subsequent vowels have predictable height. Odden (1991, 1996) accounts for this fact by positing a process of vowel harmony by which all non-stem-initial vowels harmonize with the initial for height.[30] While this generalization holds for stems, verbal extensions (suffixes) alternate in agreement with the height of the preceding stem vowel as shown in (4.2). The low vowel [a] does not undergo harmony, and blocks it so that all subsequent vowels are high as seen in examples such as *kɪŋagiya* 'cause to follow' where the causative suffix *-iy-* is a high vowel while the stem-initial is [ɪ].

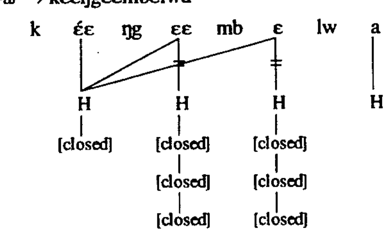
(4.2) Complete height harmony in Kimatuumbi.

a.	ásim-i̱lw-a	'be borrowed'
	ín-i̱lw-a	'be danced'
	kún-i̱lw-a	'be grated'
	twíɪk-ɪ̱lw-a	'be lifted'
	ʊ́ʊg-ɪ̱lw-a	'be bathed'
	kɛ́ɛŋgɛɛmb-ɛ̱lw-a	'be uprooted'
	bɔ́ɔl-ɛ̱lw-a	'be de-barked'
b.	čáag-i̱y-a	'cause to grind'
	číinǰ-i̱y-a	'cause to slaughter'
	kɪ́ŋag-iy-a	'cause to follow'
	ʊ́ʊg-ɪ̱y-a	'cause to bathe'
	čɛ́ɛŋg-ɛ̱y-a	'cause to build'
	bɔ́ɔl-ɛ̱y-a	'cause to tear bark'
c.	út-i̱k-a	'be pullable'
	búundal-i̱k-a	'be bluntable'
	kʊ́ʊl-ɪ̱k-a	'be pulled'
	kɛ́t-ɛ̱k-a	'be cut up'

Odden's (1991, 1996) account of these facts is to posit that all non-stem-initial vowels are of the set [i u a]. Of these, [i u] harmonize with the initial while [a] blocks. All vowels subsequent to [a] remain either high or low, i.e., from the set [i u a]. In all cases in which harmony applies, the trigger and target surface with the same height, constituting a complete height harmony.

Complete height harmony in Kimatuumbi is formalized as the simultaneous assimilation of all height features (Odden 1991, 1996; Clements 1989, 1991; Parkinson 1994). No single height feature can account for the full range of alternations exhibited by the harmonizing vowels in (4.2). The simultaneous assimilation of all height features results in a structure in which the Height node of the initial vowel is multiply linked to all subsequent non-low vowels (Odden 1991, 1996; Clements 1989, 1991; Parkinson 1994).

(4.3) /kɛɛŋgiimb-ilw-a/ → kɛ́ɛŋgɛɛmbɛlwa



As the Height node (represented by H in (4.3)) is linked across the stem, the existing height nodes of the harmonizing vowels are delinked. The opacity of the vowel [a] is attributed to the enforcement of HEIGHTPL which requires that a vowel specified for an occurrence of [closed] also be specified for a peripheral place (cf. §3.1.1).

(4.4) Align(Height[cl], R, Word, R).

> **ALIGN[HT]** = for all vowels specified for [closed], there exists a Height node such that the right edge of that node and the right edge of the word coincide.

Since HEIGHTPL is ranked above ALIGNHT, the low vowel [a] cannot undergo harmony. As the final vowel in each example in (4.2) is [a], ALIGNHt is partially violated. Satisfying ALIGNHT incurs a MAX[cl] violation since the occurrences of [closed] that specify a stem-medial vowel in the input are not parsed in the output. The multiple linking of the stem-initial Height node may proceed left to right until a low vowel appears.

[30] An general exception to this pattern that does not effect the analysis presented here concerns the vowel [u] which assimilates to all non-low vowels except [ɛ]. Thus *tɪkʊ̱-ly-a* 'break with' and *bɔmɔ̱-lw-a* 'be destroyed' but *čɛku̱-ly-a* 'shave with.'

Tableau 4.1

ʊʊgilwa → ʊ́ʊgɪlwa	HEIGHTPL	IDENT[dor]	IDENT[cor]	ALIGN[cl]	MAX[cl]
a. ☞ ʊʊg ɪlw a H <H> H				*	***
b. ʊʊg ilw a H H H				**!	
c. ʊʊg ɪlw ʌ H <H> <H>	*!				******
d. ʊʊg ɪlw ɪ H <H> <H> [cor]			*!		******
e. ʊʊg ɪlw ʊ H <H> <H> [dor]		*!			******

As discussed in the previous chapter (§3.1.4), the opacity of [a] could also be attributed explicitly to the fact that this is a low vowel rather than, as above, to the placelessness of [a]. As no language requires the explicit exclusion of low vowels (because, for example, [æ] or [ɒ] do not raise), the opacity of [a] is attributed to the interaction of the independently motivated constraints for the identity of place and HEIGHTPL.

4.1.1.2 Kikuria

Kikuria (Chacha and Odden 1994, Cammenga 1994, Parkinson 1994, §3.1.10) exhibits complete height harmony. Kikuria vowels are listed in (4.5).

(4.5) Kikuria vowels.

i		u
e		o
ɛ		ɔ
	a	

The vowels /e o/ are lowered to [ɛ ɔ] when preceded by [ɛ ɔ], as seen in the following examples. Here, the vowel of the applied suffix, *-er-*, is lowered to [ɛ] when the preceding vowel is [ɛ ɔ].

(4.6) Complete height harmony in Kikuria.

u-gu-suraaŋg-er-a	'to praise for'
o-go-taaŋgat-er-a	'to lead for'
o-ko-hoor-er-a	'to thresh for'
o-ko-rɔg-ɛ̲r-a	'to bewitch for'
o-ko-gɔɔg-ɛ̲r-a	'to slaughter for'
o-go-sɔk-ɛ̲r-a	'to poke for'
o-go-tɛrɛk-ɛ̲r-a	'to brew for'

The harmony displayed in (4.6) is an assimilation for all height features, expressed as an assimilation of the Height node. Notice that the trigger and target emerge as the same height as a result of this assimilation.

(4.7) Align(Height, R, Word, R)

ALIGNHTR = for all vowels specified for [closed], there exists a Height node such that the Right edge of the Height and the Right edge of the word coincide.

ALIGNHT is ranked above IDEN[cl] as demonstrated in the following tableau.

Tableau 4.2

-rɔg-er → rɔg-ɛr-	ALIGNHTR	IDENT[cl]
a. ☞ ɔ ɛ HT <HT>		*
b. ɔ e HT HT	*!	

The vowel [a] does not undergo harmony since linking a Height node to this vowel violates an identity of place constraint or HEIGHTPL.

Tableau 4.3

rɔg-ɛr-a → rɔg-er-a	HEIGHTPL	IDENTPL	ALIGNHTR
a. ☞ rɔg ɛr a HT <HT> HT			*
b. rɔg ɛr ə HT <HT> <HT>	*!		
c. rɔg ɛr ɔ HT <HT> <HT>		*!	

High vowels are lowered to [e o] when followed by these vowels. While prefixes do not undergo the process, high vowels in roots do lower when followed by suffixes containing [e o]. Examples of High Vowel Lowering are provided in (4.8) below. The applied suffix *-er*, the stative suffix *-ok*, and the reversive suffix *-or* all trigger the harmony.

(4.8) High vowel lowering.

ogo-séék-ér-á	'to close for'	ugu-síík-á	'to close'
oko-róg-ér-ǎ	'to cook for'	uku-rúg-a	'to cook'
oko-hót-ók-ǎ	'to disappear by rubbing'	uku-hút-a	'to rub oof'
oko-réb-ór-ǎ	'to unblock'	uku-ríb-a	'to block'
ogo-tók-ór-ǎ	'to dig up'	ugu-túk-a	'to dig'

Note that while the height of infinitival prefix vowels varies in the examples in (4.8), this alternation is the result of the application (and non-application) of partial height harmony §3.1.10).

High vowel lowering is described in terms of an alignment constraint. This constraint requires that the height node be aligned to the left edge of the stem.

(4.9) ALIGN(Height Suffix, L, Stem, L).

ALIGNHTL = For all vowels specified for [closed], there exists a Height node such that the Left edge of Height and the Left edge of the word coincide.

Satisfaction of ALIGNHTL results in a violation of the lower ranked constraint IDENT[cl].

Tableau 4.4

-síík-ér- → sɛ́ɛ́k-ér	ALIGNHTL	IDENT[cl]
a. ☞ ɛ́ɛ́ é <HT> HT		*
b. íí é HT HT	*!	

Examples such as *oko-hóór-ér-á* 'to thresh for' (cf. *oko-hóór-á* 'to thresh') and *ogo-sár-ék-ă* 'to be destroyed' demonstrate that High vowel lowering does not apply to vowels other than [i u]. Failure to multiply link the Height node of the suffix vowel to the root does not incur a violation of ALIGNHTL, as defined in (4.9).

Tableau 4.5

-sár-ék- → -sár-ék	ALIGNHTL	IDENT[cl]
a. ☞ á é HT HT		
b. ɜ́ é <HT> HT		*!

4.1.1.3 Ewe

Complete height harmony is also found in several dialects of Ewe (Westerman 1930; Clements 1974, 1989; Odden 1991; Wiswall 1991; Goad 1993). Ewe has the vowels in (4.10). The high vowels in Ewe are specified for two occurrences of [closed], the mid vowels [e ɜ o] are specified for a single occurrence of [closed], and the low vowels [ɛ a ɔ] are specified for no occurrences of [closed].

(4.10) Ewe vowels.

i		u
e	ɜ	o
ɛ	a	ɔ

Harmony is seen in the examples in (4.11) from the Adangbe dialect (Clements 1974), where the height of the suffix vowel is the same as that of the preceding root vowel. The suffix is a front vowel, but surfaces as a [i] after after [i u], as [e] after [e ɜ o], and as [ɛ] after [ɛ a ɔ]. An independent process fronts the central vowels [ɜ a] when adjacent to a front vowel (Clements 1974:290)).

(4.11) Height Harmony in Ewe.

ɜ̀si í	'it's water'	
àvù í	'it's a dog'	
ye é	'it's a spider'	
ɜɲe é	'it's me'	(← /ɜɲɜ é/)
ɜwo é	'it's you'	
ɜ̀ulɛ ɛ́	'it's a weaver bird'	
àgbɛ̀ ɛ̀	'it's a load'	(← /àgbà é/)
ɜ̀sɜ́ ɛ́	'its a horse'	

Since the harmonizing vowel is the same height as the trigger (the last vowel of the root in (4.11)), Ewe harmony is a complete height harmony—a simultaneous assimilation for all height features (Clements 1989, Odden 1991). The multiple linking of the Height node is motivated by the constraint ALIGNHT.

(4.12) Align Height.

ALIGNHT = for all vowels specified for [closed], there exists a Height node such that the Right edge of the Height and the Right edge of the word coincide.

ALIGNHT is satisfied if the Height node of the rightmost stem vowel is multiply linked to the suffix vowel. In bisylabic roots, the rightmost Height node is multiply linked since multiply linking the leftmost vowel's height incurs an additional IDEN[cl] violation.

Tableau 4.6

avu-e → avu-i	ALIGNHT	IDEN[cl]
a. ☞ a u i HT HT <HT>		**
b. a u e HT HT HT	*!	
c. a ɔ ɛ HT <HT> <HT>		***!**

4.1.1.4 Tibetan

Lhasa Tibetan (Dawson 1980, Salting 1995), a Sino-Tibetan language, also exhibits complete height harmony. Tibetan has the vowels in (4.13). Dawson (1980) analyzes the Tibetan system as having two heights, high and non-high, characterized in the Incremental Constriction Model by the presence and absence (respectively) of the feature [closed].

(4.13) Tibetan vowels.

	high						non-high					
	i	ü	u	ɪ	ʊ	ə	e	ö	o	ɛ	ɔ	a
[coronal]	•	•		•			•	•		•		
[dorsal]			•		•				•		•	
[labial]		•	•		•			•	•		•	
[pharyngeal]				•	•	•				•	•	•
[closed]	•	•	•	•	•	•						

The feature [pharyngeal][31] distinguishes pairs of vowels of the same height and place such as [e] versus [ɛ] and [u] versus [ʊ] (Dawson 1980:51–58). While minimal pairs such as *šee* 'get (honorific)' versus *šɛɛ* 'say' demonstrate that constriction is contrastive in Tibetan, vowels may acquire the feature [pharyngeal] by rule. Vowels exhibit an alternation by which certain suffixes trigger the "constriction" of stem-final vowels. In the examples in (4.14), the suffix marking the dative/locative case triggers the constriction and lengthening of the stem-final vowel (Dawson 1980).

(4.14) Constriction.

nom	*dat/loc*	*gloss*
pʰöpa	pʰöpaa	'Tibetan'
yiqi	yiqɪɪ	'letter'
qʰare	qʰarɛɛ	'what'
puqu	puqʊʊ	'child'
qʰotso	qʰotsɔɔ	'them'

Complete height harmony is found in Tibetan whereby suffixes with high vowels trigger the complete raising of the stems to which they attach. Examples of Tibetan raising are seen in (4.15) where the future tense marking suffix *-qi* triggers complete height harmony of the preceding stem.

(4.15) Complete height harmony in Tibetan.

	root	*future*	*gloss*
a.	šaa-	šəə-qi-	'leave'
	yaa-	yəə-qi-	'borrow'
	sɛ-	sɪ-qi-	'hear (honorific)'
	ɲɛɛ-	ɲɪɪ-qi-	'sleep'
	tee-	tii-qi-	'give'
	kee-	kii-qi-	'be born'
	lɔɔ-	lʊʊ-qi-	'read'
	šɔɔ-	šʊʊ-qi-	'lose'
	qʰo-	qʰu-qi-	'hear'
	pʰöö-	pʰʊʊ-qi-	'flee'
	qʰö-	qʰʊ-qi-	'wear'
b.	nii-	nii-qi-	'find'
	tʰuu-	tʰuu-qi-	'drink'
	tsüü-	tsüü-qi-	'offer'

[31] Dawson uses the feature [constricted] to denote pharyngeal constriction. The feature [pharyngeal] is used here for consistency.

The examples in (4.15.b) demonstrate that high vowels do not alternate in the raising context. The examples in (4.16) demonstrate that other high voweled suffixes also trigger raising. (See Dawson (1980) for additional raising suffixes.)

(4.16) Additional raising suffixes.

root	*gloss*	*negative*	*'when'*
naa	'do'	nəə-ku	nəə-tüü
tee	'give'	tii-ku	tii-tüü
ɲɛɛ	'sleep'	ɲɪɪ-ku	ɲɪɪ-tüü
tsoo	'sell'	tsuu-ku	tsuu-tüü
pʰöö	'flee'	pʰüü-ku	pʰüü-tüü
lɔɔ	'read'	lʊʊ-ku	lʊʊ-tüü

Alternations such as *ma-tee-* 'give' versus *mə-lɪɪ-* 'arrive' and *mə-lüü-* 'return' demonstrate both that the high vowels [ɪ ʊ] trigger raising and that high root vowels trigger the process in prefixes (Dawson 1980:71).

Raising is also progressive as seen in the examples in (4.17). Here, compounds in which the left member contains a high vowel trigger raising of a following non-high vowel.

(4.17) Progressive raising.

ri 'mountain'	tse 'tip, peak'	→	ri-tsi 'mountan top'
qu 'body'	tsʰe 'life'	→	qu-tsi 'life (honorific)'
u 'head'	ɲɛɛ 'pillow'	→	u-ɲɪɪ 'pillow (honorific)'
qu body	lɔɔ lungs	→	qu-lʊʊ 'lungs (honorific)'
u head	ṭa hair	→	u-ṭə 'hair (honorific)'

Raising is described here in terms of an alignment constraint that requires that the Height node of a high vowel is aligned to the left and right edges of a word.

(4.18) Align(Height, L/R, Word, L/R)

AlignHt = For all vowels specified for the maximum number of [closed], there exists some Height node for which the left edge of that node and the left edge of the word coincide and the right edge of that node and the right edge of the word coincide.

AlignHt is ranked above the constraint MaxHt since multiply linking a Height node requires the delinking of the node it replaces.

Tableau 4.7

qu-lɔɔ → qu-lʊʊ	AlignHt	MaxHt
a. ☞ qu lʊʊ Ht <Ht>		*

qu-lɔɔ → qu-lʊʊ	AlignHt	MaxHt
b. qu lɔɔ (Ht Ht)	*!	

The treatment provided here of Tibetan demonstrates that an account of the vowel alternations is possible within the Incremental Constriction Model.[32]

4.1.1.5 Other Cases

Some complete height harmony systems superficially appear to be counterexamples to the one-step raising generalization observed in Chapter 3. Maltese (Hume 1996) is one such example. Maltese has a five vowel system [i e a o u], specified by Hume (1996) as in (4.19) following the model presented in Clements and Hume (1995). The vowel [a] is specified as [pharyngeal] to reflect the parallels between this vowel and the guttural consonants (Hume 1994, 1996). Hume analyzes the Maltese system as contrasting two heights, characterized by the feature [open] so that the high vowels [i u] are [–open] and the non-high vowels are specified as [+open]. (The low vowel, [a], is unspecified underlyingly, but recieves a [+open] specification via a redundancy rule (Hume 1996).)

(4.19) Maltese vowels.

	i	u	e	o	a
[coronal]	•		•		
[labial]		•		•	
[pharyngeal]					•
[open]	–	–	+	+	(+)

In the Incremental Constriction Model, the Maltese system is characterized as in (4.20).

(4.20) Maltese vowels in the Incremental Constriction Model.

	i	u	e	o	a
[coronal]	•		•		
[labial]		•		•	
[pharyngeal]					•
[closed]	•	•			

Hume describes a height harmony by which the vowel [i] surfaces as [e] when followed by the vowel [a]. This process accounts for the quality of the first vowel in the examples in (4.21). For all the examples below, the first root vowel is underlyingly [i], but lowers to [e] before the following [a]. (The lowered vowel is underlined in the examples below.)

[32] Salting (1995) suggests that the processes of height harmony and laxing are problematic for the approach advocated in Clements and Hume (1995). Salting is correct in asserting that Tibetan demonstrates the need for the feature [ATR] (or equivalent), but this view is not neccessarily at odds with the Incremental Constriction Model nor the Clements and Hume model.

(4.21) A-Assimilation in Maltese.

kesah	'he got cold'
rebah	'he won'
fetah	'he opened'
felah	'he was strong'
seraʔ	'he stole'
telaʔ	'he departed'

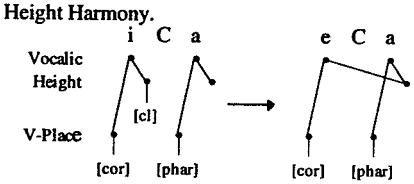
The second vowel in the examples in (4.21) is underlyingly [i], but is realized as [a] when adjacent to a guttural consonant. Stated in derivational terms,[33] the second root vowel of *fitiħ* assimilates to the following guttural consonant, emerging as [a]. The first root vowel then assimilates to the height of the follwing [a] to surface as [e] (4.22).

(4.22) fitiħ → fetaħ.

input	*guttural assimilation*	*height harmony*
/fitiħ/	fitaħ	fetaħ

While this assimilation appears to be a partial lowering, it is in fact, a complete height harmony. Recall that the vowels [e] and [a] have the same phonological height (expressed as [+open] in Hume (1996) or as having no instance of [closed] in the Incremental Constriction Model). Thus, the assimilation of /i/ to [e] in Maltese constitutes a complete height harmony. The Height node of the low vowel [a] is multiply linked to the preceding vowel. The first vowel retains its [coronal] specification, but is realized as [e] with its new Height node.

(4.23) Maltese Height Harmony.



A similar example comes from Latin (Schein and Steriade 1986:699–702). Between Old Latin and Classical Latin, the diphthongs [oy] and [ay] became [oe] and [ae], respectively. These changes are illustrated in the examples in (4.24).

(4.24) Complete height harmony in Latin.

koyrāveront	>	koerāveront	'they took care'
loydōs	>	loedōs	'games ACCUSATIVE'
aydem	>	aedem	'house ACCUSATIVE'
aykwom	>	aekwom	'equal ACCUSATIVE'

The analysis of these changes in Latin is identical to that of Maltese above. There are only two phonological heights in Latin, high and non-high. The assimilation in (4.24) is a complete height harmony where the palatal vowel emerges with the same height as the preceding non-high vowel. Height harmony in Maltese and Latin is described as an

[33] These alternations may also be described in terms of constraints.

assimilation for the entire height node since the trigger and target surface with identical heights as a result of these processes.

4.1.1.6 Comparison of Complete and Partial Height Harmonies

Complete and partial height harmonies differ both in their expression and their effect. Complete height harmony is the simultaneous assimilation of all height features while partial height harmony is an assimilation for just one height feature. Complete height harmony moves the target vowel to the exact height of the trigger while partial height harmony raises the trigger up one step. Another difference between these two types of assimilation lies in their relative maintenance of contrasts. While complete height harmony eliminates height contrasts, partial height harmony, to a greater degree, preserves them.

Compare, for example, Kimatuumbi and Nzɛbi. Both languages contrast four heights, as represented in (4.25). Kimatuumbi (cf. §4.1.1.1) exhibits complete height harmony and Nzɛbi (cf. §3.1.5) exhibits partial height harmony.

(4.25)

	Kimatuumbi			Nzɛbi		
4	i		u	i		u
3	ɪ		ʊ	e		o
2	ɛ		ɔ	ɛ		ɔ
1		a			a	

In Kimatuumbi height harmony, the height of the stem-initial vowel is spread onto all subsequent non-low vowels. As a result of complete height harmony in Kimatuumbi, all height contrasts are realized on the stem-inital vowel, the height of all subsequent vowels is predictable. In this sense, complete height harmony eliminates contrasts.

In Nzɛbi, vowels all raise one step before a high vowel suffix. Thus, /a/ raises to [ɛ], /ɛ ɔ/ raise to [e o], and /e o/ raise to [i u]. While the contrast between [e o] and [i u] is neutralized in the raising context, the contrast among the lowest three heights is maintained. In this sense, then, partial height harmony preserves contrasts (relative to complete height harmony). Of Kimatuumbi's four heights, only two are contrasted stem-medially (low and non-low). In Nzɛbi, three height contrasts are available in the harmonizing context.

The fact that the two types of assimilation are expressed in distinct terms is appropriate. The multiple linking of the Height node, in Kimatuumbi, from the stem-initial to following vowels instigates the delinking of the height nodes of the stem-medial vowels. Thus, the harmonizing vowels lose the constituent that embodies their contrastive height. In Nzɛbi, harmony is not accompanied by delinking. The underlying Height nodes of harmonizing vowels in Nzɛbi are preserved. The targets of Nzebi harmony, then, maintain their original height specifications.

4.1.2 Coalescence

Vowel hiatus, a sequence of vowels, is dispreferred cross-linguistically. In optimality theoretic terms, hiatus is a violation of ONS, the constraint that requires that all syllables have an onset. To avoid an ONS violation, GEN may resolve hiatus in a number of ways including glide-formation, deletion, epenthesis, and coalescence. The outcome of coalescence is a single vowel containing properties of both input vowels.

(4.26) Coalescence (defined).

Vowel coalescence is the resolution of two adjacent vowels into a single vowel containing properties of both input vowels.

In Sanskrit (Whitney 1889), for example, when the vowels [i u a] come in contact with each other across a word boundry, hiatus is resolved such that only one "vowel" surfaces.[34] Sanskrit appeals to three means of resolving hiatus: deletion, glide formation, and vowel coalescence, as seen in (4.27, adapted from Schane 1987:283).

(4.27) Vowel combinations in Sanskrit.

$V_2\rightarrow$ / $V_1\downarrow$	i	u	a
i	i	yu	ya
u	wi	u	wa
a	e	o	a

One could argue that combinations of *i+i → i*, *u+u → u*, and *a+a → a* constitute coalescence, an alternative in which one of the two input vowels deletes to yield the surface form. Since such examples are ambiguous, however, they are excluded from discussion here (and thus fall outside of the definition (4.26)). Similarly, the combination of distinct high vowels results in the leftmost member surfacing as a homorganic glide (i.e., undergo glide-formation). These cases, too, are not discussed here (but see Schane 1987, Lamontagne and Rosenthall 1995).

4.1.2.1 Cross-Linguistic Patterns

The relevant examples in (4.27) are those involving the low vowel [a] and a following high vowel. In these cases, the surface vowel reflects the color of the high vowel, front in the *a+i* combination and back in the *a+u* combination. It will be argued below that the input vowel [a] contributes the height of the surface vowel by "lowering" the other input vowel. The examples in (4.28) show the behavior of combinations in which one of the two input vowels is [a] (Whitney 1889:43).

(4.28) Sanskrit vowel mergers involving *a*.

a + i → e
/rāja-indra/ → rājendra 'supreme sovereign'
a + u → o
/hita-upadeçaḥ/ → hitopadeçaḥ 'friendly advice'

Kimatuumbi (Odden 1996), a Bantu language (P13) spoken in Tanzania, also exhibits coalescence. Recall from §2.4.3 that Kimatuumbi contrasts the vowels in (4.29). Length is contrastive in Kimatuumbi, so each vowel below also has a long counterpart.

(4.29) Kimatuumbi vowels.

i		u
ɪ		ʊ
ɛ		ɔ
	a	

[34] In languages with contrastive vowel length, the output of coalescence is always a long vowel (de Haas 1987, 1988). Issues concerning vowel length are largely ignored here.

Coalescence optionally applies when the short vowel [a] comes in contact with the vowels [i u] in prefixes (Odden 1996:130–2). When [a] comes in contact with root vowels, no coalescence takes place. When it does apply, coalescence has the effect depicted in (4.30).

(4.30) Combinations in Kimatuumbi.

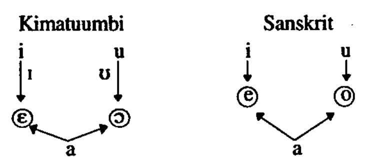
$V_2\rightarrow$ $V_1\downarrow$	i	u
a	ɛ	ɔ

Examples of coalescence are provided in (4.31) below. As this process is optional in Kimatuumbi, both options are shown, with the non-coalesced form being given first for each pair. The vowels that have undergone coalescence are underlined.

(4.31)	a-i-tɛ́liikɛ	~	ɛɛ-tɛ́liikɛ	'he cooked them'
	pa-bá-i-káatitɛ́	~	pa-bɛ́ɛ-káatitɛ́	'when they cut them'
	a-u-káatitɛ	~	ɔɔ-káatitɛ	'he cut it'
	pa-u-títili	~	pɔɔ-títili	'where the chicken louse is'

Kimatuumbi and Sanskrit have in common the fact that coalescence applies between [a] and a high vowel. While coalscence produces the mid vowels [e o] in Sanskrit, the process creates [ɛ ɔ] in Kimatuumbi. This difference is predictable from the inventories of the two languages. The coalescence of [a] with another vowel always generates a vowel of the lowest height in that language that is back or front (depending upon the other input vowel).

(4.32)



The survey of languages that follows reveals that coalescence merges two vowels so that the output preserves the height of the lower vowel and the place of the higher. The constraint PL→[cl], defined below, requires that a vowel specified for a peripheral place must also be specified for an occurrence of [closed], so that when one of the input vowels is [a], the output is specified for one occurrence of [closed] (and thus is one step higher than the input [a]).

(4.33) Cross-Linguistic patterns of Vowel Coalescence.

a. The output vowel is always the height of the lower of the two input vowels (unless one of the vowels is [a]).
b. The output vowel is front if the higher vowel is front, and back if the higher vowel is back.
c. When the lower vowel is [a], the output vowel is always the lowest front or back vowel.

The fact that it is the height of the lower vowel that is preserved in the output of coalescence may reflect the drive to maintain the most sonorous vowel possible. The following sections present an account of coalescence analyzed as a set of ranked constraints.

4.1.2.2 Kimatuumbi

Coalescence is a means of resolving hiatus to avoid an ONS violation. Languages that exhibit coalescence, therefore, rank ONS fairly high. An epenthetic consonant to form an onset would also avoid hiatus, though, so languages that exhibit coalescence must rank the the constraint DEP highly enough that candidates in which a consonant is inserted between two vowels in hiatus is a less optimal candidate. Since deleting one of the two vowels in hiatus would also resolve hiatus, the constaint MAX must also be ranked highly.

Coalescence does violate the constraint Uniformity (McCarthy and Prince 1995:371). The constraint UFORM mitigates against coalescence, since in the resolution $a+i \rightarrow e$, the output element [e] has two input correspondents ([a] and [i]). Ranking MAX above UFORM motivates the preservation of some part of both vowels in hiatus, rather than losing one vowel completely.

(4.34) Uniformity.

UFORM = no element of the output has multiple input correspondents.

The tableau below illustrates this ranking. Here, the Sanskrit input /rāja-indra/ surfaces as *rājendra* 'supreme sovereign.' Candidates in which one of the input vowels is deleted is ruled out by MAXV violations. Failure to remedy hiatus results in an ONS violation. The winning candidate violates UFORM, but satisfies all higher constraints. (Highly ranked DEP is assumed to prohibit insertion.) While the issue of exactly what constitutes a MAXV violation requires further study, it is assumed here that as long as one of the two nodes dominated by Vocalic (cf. §2.4) is faithfully parsed in the output, then MAXV is satisfied for that vowel. That is, in $a+i \rightarrow e$, the V-Place node of [i] and the Height node of [a] are faithfully parsed so that candidate (a) incurs no MAX violation in Tableau 4.8.

Tableau 4.8

CaiC→CeC	ONS	MAXV	UFORM
a. ☞ e			*
b. CaC		*!	
c. CiC		*!	
d. CaiC	*!		

Having determined the constraint ranking that achieves coalescence, some account of the quality of the surface vowel must be provided. One constraint prefers candidates which are specified for fewer instances of [closed]. All else being equal, this constraint selects [e] over [i], but [ɛ] over [e]. Stated another way, *[closed] strives to have a maximally sonorous vowel.

(4.35) Limit the number of instances of [closed].

***[closed]** = a vowel should have the fewest number of occurrences of [closed] possible.

A vowel may only have one Height node, and only one V-Place node. GEN produces no candidates with two Height nodes nor with two V-Place nodes since such structures are prohibited universally. Candidates in which the Height node of one vowel and the V-Place of another vowel are preserved are favored over those in which one of two vowels in hiatus is deleted. The former satisfy MAXV, while the latter violate MAXV. In deciding *which* height node to parse, *[closed] motivates the preservation of the Height node of the lower of the two vowels.

Tableau 4.9

e u → o	ONS	MAXV	*[closed]	UFORM
a. ☞ o			*	*
b. i			**!	*
c. e		*!	*	
d. u		*!	**	

As will be shown below, in Sayanci, which contrasts three heights among [i e a o u], the combination of [e] and [u] derives [o]. Tableau 4.9 illustrates the ranking of ONS, MAX, and *[closed] above UFORM. The winning candidate produces an [e], specified for one occurrence of [closed], corresponding to its single violation of *[closed]. This candidate also violates UFORM, but satisfies MAXV and ONS to surface as the winner. Candidate (b) also satisfies ONS and MAX, but produces an [i], which preserves the Height node of [u] and the V-Place of [e]. Since [i] is a high vowel specified for two occurrences of [closed], this candidate incurs two violations of *[closed] and is less good than (a).

The low vowel [a] is always the lower member in a pair of vowels in hiatus. Therefore, *[closed] always prefers candidates which preserve the Height node of [a] in combinations involving this vowel. The constraint PL→[cl] requires that a candidate with a place feature on the surface contain at least one occurrence of [closed] as well. Since [a] always contributes its height node, which dominates no occurrences of [closed], an occurrence of [closed] must be inserted for combinations involving this vowel and another vowel specified for a place feature.

(4.36) Place implies [closed].

PL→[cl] = if a vowel is specified for a peripheral place feature, it is also specified for at least one occurrence of [closed].

The interaction of these constraints is seen in Kimatuumbi, which contrasts the vowels in (4.37).

(4.37) Kimatuumbi vowels.

	i	u	ɪ	ʊ	ɛ	ɔ	a
[coronal]	•		•		•		
[labial]		•		•		•	
[closed]	•	•	•	•	•	•	
[closed]	•	•	•	•			
[closed]	•	•					

Recall that the vowel [a] in Kimatuumbi combines with [i] to form [ɛ] and with [u] to form [ɔ] (4.31). Kimatuumbi coalescence is depicted in Tableau 4.10.

Tableau 4.10

a i → ɛ	MAXV	PL→[cl]	*[closed]	UFORM
a. ☞ ɛ <VPL> H VPL <HT> [CL]			*	*
b. ɪ <VPL> H VPL <HT> [CL] [CL]			**!	
c. ɨ VPL <H> <VPL> HT		*!	***	*
d. æ <VPL> H VPL <HT>		*!		*
e. a	*!			

Candidate (a) violates UFORM, but is optimal because it satisfies MAXV. The vowel [a] is specified for no occurrences of [closed] in the input, and so *[closed] selects its Height node to be parsed. PL→[cl] motivates the insertion of an occurrence of [closed] onto the surface vowel so that the outcome is a front vowel with only once instance of [closed], which incurs a single violation of *[closed]. Candidate (b) inserts two occurrences of [closed], thereby satisfying PL→[cl], but multiply violating *[closed]. Candidate (d) completely satisfies *[closed], but fails for its PL→[cl] violation. Candidate (c) preserves the Height node of [i] and the V-Place node of the central vowel [a], thus incurring three violations of *[closed].

Tableau 4.11

a u → ɔ	MAXV	PL→[cl]	*[closed]	UFORM
a. ☞ ɔ <VPL> H VPL <HT> [CL]			*	*
b. ɒ <VPL> H VPL <HT>		*!		*

4.1.2.3 Sayanci

A similar account can be provied for Sayanci (Schneeberg 1974), a language spoken in Nigeria. Sayanci has the five vowels in (4.38).

(4.38) Sayanci vowels.

	i	u	e	o	a
[coronal]	•		•		
[labial]		•		•	
[closed]	•	•	•	•	
[closed]	•	•			

Hiatus in Sayanci is resolved by coalescence, as shown in the examples in (4.39).

(4.39) Sayanci.

bare stem	*'the' -es*	*'my' -adn̩*	*gloss*
tlərəŋ	tlərəŋes	tlərəŋadn̩	'rope'
vi:	ve̠:s	ve̠:dn̩	'mouth'
tlu:	tlo̠:s	tlo̠:dn̩	'meat'
ŋa:	ŋa:s	ŋa:dn̩	'child'
kaɖi	daɖe̠s	kaɖe̠dn̩	'dog'
su:tu	su:to̠s	su:to̠dn̩	'evening'
kwa:te	kwa:tes	kwa:tedn̩	'shoe'
loŋga	loŋgas	longadn̩	'rabbit'
go:ro	go:ros	go:rodn̩	'kolanut'

The combinations of vowels are depicted below. Coalescence occurs only with three combinations, *i+a, u+a, u+e.*

(4.40) Sayanci combinations.

$V_2\rightarrow$ $V_1\downarrow$	e	a
i	e	e
u	o	o
e	e	e
o	o	o
a	a	a

Coalescence in Sayanci follows the pattern described in (4.33). The combinations involving the high vowels and [a] surface as the lowest vowel with the same place as the non-low input vowel. The combination of *u+e* yields [o].

(4.41)				
	i + a → e	/vi:-adn̩/	→	ve:dn̩
	u + e → o	/tlu:-es/	→	tlo:s
	u + a → o	/tlu:-adn̩/	→	tlo:dn̩

The account of the /u-a/ combination, as in /tlu:-adn̩/ → [tlo:dn̩] 'my meat' and of /u-e/ combinations, as in /tlu:-es/ → [tlo:s] 'the meat,' is presented in the following tableaux. In the /u-a/ combination, an occurrence of [closed] is inserted by GEN to avoid a PL→[cl] violation. In the /u-e/ combination, no occurrence of [closed] is inserted since [e], which is specified for an occurrence of [closed], contributes its Height node.

Tableau 4.12

u a → o	ONS	MAXV	PL→[cl]	*[closed]
a. ☞ o: V-Pl <H> <V-Pl> H [cl]				*
b. ɒ: V-Pl <H><V-Pl> H			*!	
c. u		*!		**
d. a		*!		
e. u: V-Pl H a: V-Pl H	*!			**

When [u] and [a] coalesce, [u] contributes its place while the lower vowel [a] contributes its height. Since PL→[cl] is highly ranked in Sayanci, the optimal candidate, (a) in Tableau 4.12, is one in which an occurrence of [closed] is inserted. In the combination of [u] and [e], again [u] contributes its place while [e] contributes its height. The output vowel is, therefore [o].

Tableau 4.13

u e → o	ONS	MAXV	PL→[cl]	*[closed]
a. ☞ o: V-Pl <H> <V-Pl> H				*
b. ɒ: V-Pl <H><V-Pl> H <[cl]>			*!	

Candidate (b) in Tableau 4.13 preserves the V-Place of [u] and the Height of [e], but deletes an occurrence of [closed]. While this move satisfies *[closed] completely, it violates PL→[cl].

4.1.2.4 Tigrinya

Coalescence is also found in Tigrinya (Buckley 1993). Coalescence (as defined in (4.26) in Tigrinya only involves the central vowel [ʌ]. Tigrinya vowels are in (4.42).

(4.42) Tigrinya vowels.

a.

i	ɨ	u
e	ʌ	o
	a	

b.

	i	ɨ	u	e	ʌ	o	a
[coronal]	•			•			
[labial]			•			•	
[closed]	•	•	•	•	•	•	
[closed]	•	•	•				

Vowel combinations are provided below. Coalescence only occurs when [ʌ] is followed by a high vowel,[35] i.e., *ʌ+i*, *ʌ+u*. (The empty cells in (4.43) indicate that such combinations are unattested.)

(4.43) Tigrinya combinations.

V₂→ V₁↓	i	u	e	o	a
ɨ	ɨ	u			
ʌ	e	o	e	o	a

Again, coalescence in Tigrinya follows the pattern established in (4.33). The outcome of combinations with [ʌ] result in a mid vowel of the place of the other input vowel. The placeless vowel, [ʌ], of Tigrinya coalesces with the high vowels [i u], contributing only its height. The outcome is back in combination with [u], and front in combination with [i].

Tableau 4.14

ʌ i → e	ONS	MAXV	*[closed]
a. ☞ e			*
b. ɨ			**!
c. ʌ		*!	*
d. ʌ i	*!		

Candidate (b) in Tableau 4.14 preserves the Height node of input [i] and the V-Place of the central vowel [ʌ], and fails because it incurs an extra violation of *[closed]. Candidate (c), in which input [i] is deleted suffers a MAXV violation while (d) fails to satisfy ONS.

4.1.2.5 Other Cases

Coalescence is also found in the Old Moshi dialect of Chagga (Saloné 1980). Chagga has the vowels [i e a o u]. Combinations of vowels are represented in (4.44).

(4.44) Chagga combinations.

V₂→ V₁↓	i	u	e	a
i			e	ya
u		u	o	o
e	e			
a			e	a

[35] The combinations of [ʌ]+[e o a] are not analyzed as coalescence here since an alternative account in terms of deletion is available.

The only combinations that result in coalescence are /u e/ and /u a/, both of which resolve to [o], as seen in (4.45). Thus, Chagga coalescence is consistent with the observations in (4.33).

(4.45) Chagga compromise.

u + e → o			
/nú-édèdá/	→	nódédà	'you will speak'
u + a → o			
/lù-á-kúďikà/	→	lókúďikà	'we (recently) carried'

The analysis of Chagga follows that of Sayanci above.

nu-ededa→noodeda	ONS	MAXV	PL→[cl]	*[closed]	UFORM
a. oo				*	*
b. ii				**!	*
c. ɒɒ			*!		*
d. ee		*!		*	
e. ue	*			***	

Candidate (a) preserves the input Height node of the lower vowel, [e], and the V-Place node of [u] producing [o]. Candidate (b) preserves the Height node of the input [u] and the V-Place node of the input [e] yielding [i], thereby incurring a second, fatal violation of *[closed]. Candidate (c) preserves the Height node of the input [e] but deletes one occurrence of [closed] so that this form violates PL→[cl].

Quebec French has the vowels in (4.46) among which heights are contrasted as well as front rounded vowels.

(4.46) Quebec French vowels.

	i	ü	u	e	ö	o	ɛ	œ	ɔ	a
[coronal]	•	•		•	•		•	•		
[dorsal]			•			•			•	
[labial]		•	•		•	•		•	•	
[closed]	•	•	•	•	•	•	•	•	•	
[closed]	•	•	•	•	•	•				
[closed]	•	•	•							

Coalescence in Quebec French involves the combinations in (4.47).

(4.47) Quebec French.

a + i → ɛ
a + e → ɛ
a + u → ɔ
a + o → ɔ
a + ü → œ
a + ö → œ

While Quebec French contrasts more vowels an the languages discussed above, the pattern noted in (4.33) still holds for the pattern observed in this language. The surface vowel in each outcome in (4.47) is the lowest possible vowel of the same place of the non-low input vowel. In combinations involving the front rounded vowels, the outcome is a front rounded vowel, preserving the entire vowel place constituent.

Tableau 4.15

a ü → œ	MAXV	PL→[cl]	*[closed]
a. ☞ œ <VPL> H VPL <H> [cl] [cor] [lab]			*
b. i VPL <H> <VPL> H			**!*
c. ɛ <VPL> H <H> [cl] [cor] [lab]	*!		*
d. ɔ <VPL> H <H> [cl] [cor] [lab]	*!		*

Candidates (c, d) in Tableau 4.15 do not faithfully parse the entire V-Place constituent of either vowel, and are therefore ruled out on the basis of that MAXV violation. Candidate (a) faithfully parses the Height node of [a] and the V-Place node of [ü]. Since [a] has no occurrences of [closed] of its own, PL→[cl] motivates the insertion of a single instance of this feature.

4.1.3 Diphthongization

This section surveys the process of diphthongization as it relates to vowel height. A *diphthong* is a dynamic syllable nucleus where the quality of the nucleus changes from beginning to end. *Diphthongization*, or *breaking*, is the process by which a vowel of uniform quality (i.e., a *monophthong*) is converted into a diphthong. Diphthongization often involves a change in vowel place, a change of height, or both. As vowel height is the primary concern of this dissertation, only diphthongization involving height is discussed here. Vowel place changes are only addressed when they are driven by place/height dependencies.

4.1.3.1 Eastern Finnish

In Eastern Finnish (Kiparsky 1968) for example, long vowels break into diphthongs so the [e:] is realized as [ie]. The monophthong [e:] is understood to be of uniform quality throughout while the diphthong [ie] begins with a higher quality and ends with a lower quality. Diphthongization in Eastern Finnish is shown in (4.48.a).

(4.48) Eastern Finnish

e e	→	ie
o o	→	uo
ö ö	→	üö
æ æ	→	eæ
a a	→	oa

Eastern Finnish vowels are specified as below in the Incremental Constriction Model.

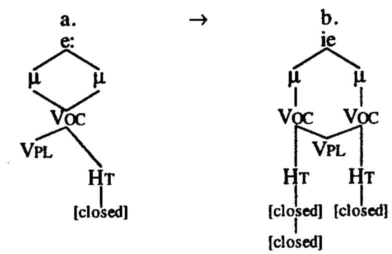
(4.49)

	i	ü	u	e	ö	o	æ	a
[coronal]	•	•		•	•		•	
[dorsal]			•			•		•
[labial]		•	•		•	•		
[closed]	•	•	•	•	•	•		
[closed]	•	•	•					

Diphthongs in Eastern Finnish have a dynamic quality in that their left edge is one step higher than the height of its monophthongal counterpart, and the right edge is of the same height as the monophthong. The color of Eastern Finnish diphthongs remains uniform (except for *a* → *oa* discussed below) from edge to edge, as only height changes. Since there are no non-low back unrounded vowels in Eastern Finnish, in *a* → *oa*, the left edge of the diphthong is one step higher than [a], but this vowel becomes round through structure preservation.

The representation of a long vowel is such that a single vowel quality (represented by the Vocalic node (Clements and Hume 1994)) is associated to two timing slots (moras in (4.50.a)). In diphthongization, this structure is converted into one in which each mora is associated with a distinct height (i.e., set of [closed] specifications).

(4.50)



The exact manner in which diphthongization is to be formalized is discussed by a number of authors (Hayes 1990, Schane 1995, and references therein). The challenge in expressing diphthongization lies in the fact the structure of the monophthong is split so that some elements are associated with both moras in the diphthong while other elements are associated only with one mora in the outcome.

In Eastern Finnish, a long vowel with a single Vocalic node, a single Vowel Place node, and a single Height node are underlyingly associated to both moras. In its diphthongal counterpart, each mora is associated to its own Vocalic node and its own height node, though the Vowel Place node may be associated to both timing elements. Several steps appear neccessary to move from (4.50.a) to (4.50.b).

In Optimality Theory (Prince and Smolensky 1993), the special problem that diphthongization poses (Hayes 1990) is eliminated. The GEN component is powerful enough to generate, from the input (4.50.a), a range of structures (Prince and Smolensky 1993) including one similar to (4.50.b). Ordinarily, such changes of an underlying structure are not optimal because of the number of faithfulness violations that such an alteration incurs. Eastern Finnish, then, must highly rank a constraint that prefers the structure in (4.50.b).

The breaking effect of diphthongization can be analyzed as a constraint by which identical tautosyllabic (or tautonucleic) moras are prohibited. This constraint, (4.51), disallows monophthongal long vowels, requiring that each mora of a long vowel be different. A constraint against long vowels may lie at the heart of DIPH, forcing bimoraic vowels to surface with different qualities assigned to each mora.

(4.51) Diphthongize.

DIPH = if two moras form the nucleus of a single syllable, then the two moras must be distinct.

Languages with long vowels rampantly violate DIPH, reflecting a low ranking of this constraint in these languages. Mitigating against DIPH is the Integrity constraint (McCarthy and Prince 1995:372) in (4.52). Diphthongization violates INTEG since an input vowel of a single quality corresponds to two distinct vocoids in the output.

(4.52) Integrity

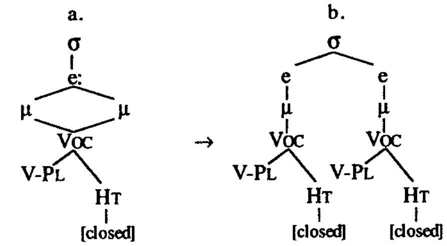
INTEG = no element in the input has multiple output correspondents.

In languages in which DIPH is ranked high, this constraint is satisfied by altering part of the input vowel, incurring an identity constraint. The fact that the change in quality found in Eastern Finnish diphthongs involves height, and not place features, is attributed to the relatively higher ranking of place identity to IDENT[cl]. This ranking ensures that a long vowel candidate which satisfies DIPH by changing a place feature will incur a violation of IDENT[lab] or IDENT[cor], both of which are ranked above IDENT[cl], making such a candidate less optimal than one that satisfies IDENT[dor] and IDENT[cor] but violates IDENT[cl].

(4.53) IDENTPLACE » IDENT[cl]

The fact that Eastern Finnish diphthongization involves raising is attributed to the constraint MAX[cl] (defined in §3.1 of the previous chapter) which prohibits deletion of an occurrence of [closed]. Among the candidates GEN produces from the input /e:/, are candidates in which the representation in (4.50.a) has undergone cloning—the process by which a set of specifications that is multiply linked to two timing elements is duplicated so that each timing unit is associated to a distinct "copy" of the feature specification set (Hume 1994, Bradshaw 1996).

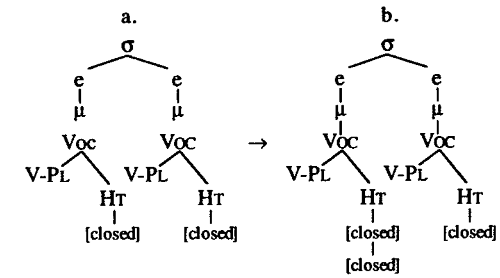
(4.54) Cloning.



The result of cloning is that each mora is specified for exactly the same features since each feature (or node) is the "clone" of its input correspondent. (The place feature [coronal] is omitted for clarity.) Cloning in and of itself does not incur any identity violations since each mora is specified for exactly the same features in (4.54.a) and (4.54.b).

The cloned sturcture in (4.54.b) does not satisfy DIPH as both moras are the same. This constraint is satisfied if an occurrence of [closed] is inserted and affiliated with one of the two moras.

(4.55)



While diphthongization averts long vowels, languages show preferences for either opening diphthongs or closing diphthongs. In an *opening* dipthong, the second element is more open (i.e., less constricted) than the first. In a *closing* diphthong, the second element is more closed (i.e., more constricted) than the first.[36] Eastern Finnish prefers opening diphthongs as [ie] and [uo] result from diphthongization while their closing counterparts, [ei] and [ou], do not surface from long mid vowels. The fact that the inserted occurrence of [closed] is associated to the leftmost mora is attributed to a constraint barring closing diphthongs.

[36] The terms "opening" and "closing" are from Catford (1977:216–7) and are adopted here to avoid the ambiguity of the terms "rising" and "falling" which variably refer to the degree of constriction of the two elements, or the headedness of the nucleus.

(4.56) No Closing Diphthongs.

***CLOSING** = the second element of a diphthong may not be more constricted than the first (i.e., *ie* but **ei*).

The structure in (4.55.b is the winning candidate, (a), in Tableau 4.16. Since in this structure, an occurrence of [closed] is inserted, this candidate violates IDENT[cl], but no higher ranked constraints, and so, is optimal. Candidate (b) fails because it violates *CLOSING by associating [closed] to the rightmost mora. Candidate (c) fails because it satisfies DIPH by deleting the [cor] specification of one of the moras. Candidate (d) similarly fails because it changes the place specification of one of the moras by inserting [dorsal]. Candidate (e) fails because while it is a completely faithful output, failing no other constraint, it violates DIPH. Candidate (f) does not undergo cloning, and inserts an occurrence of [closed] onto both moras, violating DIPH. Candidate (g) fails because it satisfies DIPH and *CLOSING by deleting an occurrence of [closed] from the rightmost mora, thus violating MAX[cl].

Tableau 4.16

ee → ie	MAX[cl]	DIPH	IDENT[dor]	IDENT[cor]	*CLOSING	INTEG
a. ☞ i e ([cl] on i)						*
b. e i ([cl] on i)					*!	*
c. ə e <[cor]>				*!		*
d. o e ([dor] on o)			*!	*		*
e. e e		*!				
f. ii ([cl])		*!				
g. e æ <[cl]>	*!					*

Eastern Finnish does not have a back non-low unrounded vowel, [ʌ], and so when the low vowel [a] diphthongizes, the left edge surfaces as round. That is, [a] diphthongizes to [oa]. This is attributed to a constraint in Eastern Finnish that requires a non-low back vowel to surface as round.

(4.57) Height–round dependency.

[cl]→[lab] = if a vowel is specified for [dorsal] and for [closed], then it must also be specified as [labial].

[cl]→[lab] motivates the insertion of an occurrence of [labial] upon the first part of the output of the diphthongization of [a]. Since DIPH requires an occurrence of [closed] to be parsed onto the first mora of the input /aa/, the optimal candidate is one in which [cl]→[lab] is satisfied by the concomitant insertion of [labial].

Tableau 4.17

aa → oa	DIPH	IDENT[dor]	*CLOSING	cl→lab	INTEG
a. ☞ o a ([closed] [lab])					*
b. ʌ a ([cl])				*!	*
c. a o ([lab] [cl])			*!		*
d. ɐ a ([cl] <[dor]>)		*!			*
e. e a ([cl] [cor])		*!			*
f. a a	*!				

4.1.3.2 Old French

In the diachrony of French, the mid vowels [e] and [o] diphthongized into the closing diphthongs [ei] and [ou] (Machonis 1990). In this language (and others exhibiting opening diphthongization, e.g., Old Prussian, Czech), the constraint *CLOSING is outranked by *OPEN.

(4.58) No Opening Diphthongs.

***OPEN** = the second element of a diphthong may not be less constricted than the first (i.e., *ei* but **ie*).

The ranking of *OPEN over *CLOSING achieves the desired results.

Tableau 4.18

o: → ou	MAX[cl]	DIPH	*OPEN	IDENT[cl]	*CLOSE
a. ☞ o u [cl]				*	*
b. u o [cl]			*!	*	
c. o o		*!			
d. o ɔ <[cl]>	*!			*	

4.1.3.3 Southern Same

In Southern Same (Lappish) (McCawley 1973), opening diphthongs surface from long vowels. In contrast to Eastern Finnish, however, the opening diphthong is created by lowering the right edge (rather than raising the left).

(4.59) Sothern Same.

i i	→	ie
u u	→	uo
ü ü	→	üö
e e	→	eæ
o o	→	oa

In languages that exhibit this type of diphthongization, MAX[cl] is ranked below the faithfulness constraint DEP[cl].

(4.60) Dependency of [closed].

DEP[cl] = if a sound is specified for an occurrence of [closed] in the output, this feature must be present in its input correspondent.

McCarthy and Prince (1995) originally describe the dependency family of constraints in terms of segments. It was argued above (Chapter 3) and in Lombardi (1995) that MAX constraints, defined in terms of segments in McCarthy and Prince (1995), must be feature-specific. Similarly, the constraint in (4.60) is a feature-specific constraint. DEP[cl] is ranked higher than MAX[cl] in Southern Lappish, as demonstrated by the following tableau.

Tableau 4.19

ee → eæ	DEP[cl]	DIPH	MAX[cl]
a. ☞ e æ <[cl]>			*!
b. e i [cl]	*!		
e e		*!	

The *CLOSE constraint is also highly ranked in Southern Same. Highly ranked DEP prevents insertion of an inctance of [closed] so that DIPH is satisfied via deletion. *CLOSING ensures that [closed] is deleted from the right portion of the long vowel.

Tableau 4.20

e: → eæ	DEP[cl]	*CLOSE	INTEG
a. ☞ e æ <[cl]>			*
b. æ e <[cl]>		*!	*
c. i e [cl]	*!		*

Since Southern Same does not have a low rounded vowel, [ɒ], the constraint [lab]→[cl] is active in this language. This constraint prohibits low rounded vowels.

(4.61) Labial implies [closed].

[lab]→[cl] = if a vowel is specified for [labial], it must also be specified for at least one occurrence of [closed].

This constraint is ranked above IDENT[lab] and IDENT[cl], as shown in Tableau 4.21.

Tableau 4.21

o: → oa	DIPH	*CLOSE	lab→cl	IDENT[lab]
a. ☞ o a <[lab]> <[cl]>				*
b. o ɒ <[cl]>			*!	
c. a o <[lab]> <[cl]>		*!		*
d. o o	*!			
e. ɒ ɒ <[cl]> <[cl]>	*!		**	
f. a a <[lb]> <[cl]> <[lb]><[cl]>	*!			**

Candidate (a) is optimal in spite of violating both IDENT[lab] and IDENT[cl] because it satisfies all higher ranked constraints. Candidate (b) satisfies IDENT[lab] but violates [lab]→[cl], and is therefore, ruled out. Candidate (c) fails because it violates *CLOSE and candidate (d) fails because it violates DIPH. Candidate (e) deletes [closed] from both vowels, and candidate (f) deletes both [closed] and [labial] from both vowels. These candidates are ruled-out because violate DIPH.

4.1.3.4 Malmö Swedish.

Bruce (1970, see also Lindau 1978, Yip 1980, Hayes 1990, Schane 1995) describe the Scanian dialect of Swedish spoken in the town of Malmö in southern Sweden. The vowels [ü ö œ] are front rounded vowels. The vowel [ʉ] is central and round. (See Appendix A for the correspondences[37] between the symbols used here and in Bruce 1970).

(4.62) Malmö vowels.

i	ü	ʉ	u
e	ö		o
ɛ	œ		ɑ
æ			

Bruce (1970:12) notes that there are four vowel heights in this language, the full range of which are contrasted among the front unround vowels [i e ɛ æ]. Thus, three occurrences of [closed] are required to characterize this inventory.

[37] The symbols [ü ö] are used here in place of [y ø] for consistency with the remainder of this dissertation as well as to avoid the ambiguity of the latter symbols.

(4.63)

	high				upper-mid			lower-mid			low
	i	ü	ʉ	u	e	ö	o	ɛ	œ	ɒ	æ
[coronal]	•	•		•	•	•		•	•		•
[dorsal]				•			•			•	
[labial]		•	•	•		•	•		•	•	
[closed]	•	•	•	•	•	•	•	•	•	•	
[closed]	•	•	•	•	•	•	•				
[closed]	•	•	•	•							

Diphthongization in Malmö is depicted in (4.64) below.

(4.64) Diphthongization in Malmö Sweedish.

i:	→	ei	ü:	→	öü	u:	→	eu
e:	→	ɛe	ʉ:	→	öʉ	o:	→	ɛo
ɛ:	→	æɛ	ö:	→	œö	ɑ:	→	æɑ

Abstracting away from the details of roundness, all descriptions of the phenomenon can be summarized as the leftmost portion of the surface diphthong is one-step lower than the input monphthong (Lindau 1978:545). Closing diphthongs in Malmö are created by deleting an occurrence of [closed] from the leftmost mora, indicating that DEP[cl] is ranked above MAX[cl]. Closing diphthongs are preferred in Malmö Swedish as *OPEN is ranked above *CLOSING.

Tableau 4.22

e: → ɛe	DEP[cl]	DIPH	*OPEN	MAX[cl]	*CLOSE
a. ☞ ɛ e <[cl]>				*	*
b. e ɛ <[cl]>			*!	*	
c. e e		*!			
d. e i [cl] [cl]	*!				*

Candidate (a) wins in because it satisfies DIPH by deleting an occurrence of [closed], and satisfies *OPEN as that instance of [closed] is from the left protion of the monophthong. Candidate (b) deletes an occurrence of [closed] from the rightmost mora and thereby fatally violates *OPEN. Candidate (c) fails as it violates DIPH. Candidate (d) satisfies DIPH and *Open by inserting an occurrence of [closed] on the rightmost mora; but thereby violates DEP[cl] and is less good than (a), which satisfies DEP[cl].

4.1.3.5 Kɔnni

Kɔnni (Cahill 1994, 1996a, b) is a Gur language spoken in Ghana. Kɔnni exhibits both cross-height vowel harmony and diphthongization. Kɔnni has three vowel heights, and contrasts a [+ATR] and [–ATR] vowel for each of the non-low heights. The Kɔnni vowels are specified as in (4.65) below.

(4.65)

	i	u	ɪ	ʊ	e	o	ɛ	ɔ	a
[coronal]	•		•		•		•		
[labial]		•		•		•		•	
[ATR]	•	•			•	•			
[closed]	•	•	•	•	•	•	•	•	
[closed]	•	•	•	•					

Cross-height harmony in Konni is shown in (4.66). Suffixes containing non-low vowels in the [-ATR] environment surface with their [+ATR] counterparts in the [+ATR] context. Thus, the suffix *rɪ* surfaces as such after [ɪ ɛ a ɔ ʊ], but as *ri* after [i e o u]. The low vowel, however, appears as [a] when in a [-ATR] envirionment, but alternates with both [e] and [o] when in a [+ATR] context (Cahill 1994, 1996a).

(4.66) ATR harmony in Kɔnni.

a.	tigi-ri	'the house'	kʊʊ-rɪ	'the hoe'
	sie-ku	'the path'	nɪɪ-kʊ	'the rain'
	tokoro-si-si	'the windows'	najʊ-sɪ-sɪ	'the flies'
b.	kuri-ye	'has pounded'	pasɪ-ya	'has peeled'
	chii-me	'carry!'	dʊ-ma	'bite!'
	tu-o	'is digging'	kʊ-a	'is killing'
	digi-wo	'cooked'	ga-wa	'went'

Cahill (1996) attributes the [a] ~ [e] ~ [o] alternation to the implicational relation between [ATR] and height such that a vowel that is specified as [+ATR] must also be specified for an occurrence of [closed]. Following (Cahill 1996), this relationship between [ATR] and [closed] is expressed in terms of the constraint in (4.67).[38]

(4.67) [ATR] Implies [closed].

PL→[cl] = if a vowel is specifed for a place feature (including [+ATR]), then that vowel must also be specified for [closed].

As found in other languages (cf. chapter 3), the constraint HEIGHTPL is highly ranked in Kɔnni. This constraint, repeated in (4.68), requires that a vowel specified for an occurrence of [closed] also be specified for peripheral place. Thus, if the vowel /a/ appears in a [+ATR] context, then it must surface with both an occurrence of [closed] and a peripheral place feature to satisfy (4.67) and (4.68) repectively.

(4.68) Height → Place.

HEIGHTPL = if a vowel is specified for an occurrence of [closed], it must also be a front or back vowel.

When /a/ appears in a [+ATR] environment immediately adjacent to a round vowel or the glide [w], it surfaces as [o]. Cahill (1996a) analyzes this as multiple linking of the feature [labial] affiliated with the preceding glide or vowel to the following vowel in order to satisfy a rule that applies to such a round vowel/glide-vowel sequence. If the vowel /a/

[38] This constraint, taken from Cahill (1996a), is actually subsumed by PL→[cl], discussed above in reference to coalescence. The constraint (4.67) is used for consistency with the original analysis of Kɔnni.

appears in a [+ATR] context but not immediately adjacent to a labial vocoid, then a default [coronal] is inserted (Hume 1994).

(4.69)

ɪCa	→	ɪCa	iCa	→	iCe
ʊCa	→	ʊCa	uCa	→	uCe
ɛCa	→	ɛCa	eCa	→	eCe
ɔCa	→	ɔCa	eCa	→	oCe
ɪa	→	ɪa	ia	→	ie
ʊa	→	ʊa	ua	→	uo
ɛa	→	ɛa	ee	→	ee
ɔa	→	ɔa	oa	→	oo
[−ATR]wa	→	[−ATR]wa	[+ATR]wa	→	[+ATR]wo

In Kɔnni, long mid vowels [ee ɛɛ oo ɔɔ] diphthongize as in (4.70). Cahill (1996b) notes that while the left half of the diphthong is always a high vowel, the right half of the diphthong behaves as though it were the low vowel /a/. That is, the second portion of the diphthong surfaces with the same quality as would /a/, subject to the same constraints at play in the harmony system of Kɔnni.

(4.70) Kɔnni diphthongization of mid vowels.

a.	b.	c.	d.
ee → ie	oo → uo	ɛɛ → ɪa	ɔɔ → ʊa

Kɔnni diphthongization is analyzed here in terms of ranked constraints. Obviously, INTEG is ranked below DIPH to tolerate the diphthongs in (4.70). Since Kɔnni diphthongs are opening diphthongs, *OPEN is ranked relatively high. Kɔnni also ranks high the constraint HILEFT, not discussed for the cases above, that requires the left half of a diphthong to be high.

(4.71) High vowel on the left.

HILEFT = the left edge of a diphthong must be specified for the maximum number of occurrences of [closed] active in the language.

Kɔnni also assigns a high rank to the constraint INTEG[cl] from the Integrity family that specificly evaluates candidates with respect to [closed].

(4.72) Ingegrity of [closed].

INTEG[cl] = no occurrence of [closed] has multiple output correspondents.

Since the input vowels all have a single occurrence of [closed], the satisfaction of HILEFT forces the insertion of an occurrence of [closed] to the left edge of the diphthong. The ranking of HILEFT, PL→[cl], INTEG[cl] is not clear from this tableau, but will be determined below.

Tableau 4.23

εε → ɪa	HiLeft	Pl→[cl]	Integ[cl]	Dep[cl]
a. ☞ ɪ a [cl] <[cor]> [cl]				*
b. ε a [cl] <[cor]>	*!			
c. ε æ [cl] [cor]	*!	*		
d. ɪ æ [cl] [cl] [cor]		*!		*
e. ɪ ε [cl] [cl] (cl)			*!	*
f. ɪ ε (cl) (cl) (cl)				**!*

Candidate (a) in Tableau 4.23 wins because it satisfies Integ[cl] by not assigning the occurrence of [closed] present in the input to both output moras. This leaves the second mora with no occurrences of [closed]. Pl→[cl] is ranked high in Kɔnni so that candidate (a) is preferred in spite of failing to parse [coronal]. If [coronal] is parsed, then an occurrence of [closed] must also be parsed to that mora. Candidate (d) violates Pl→[cl] and is, therefore, ruled out. Parsing an occurrence of [closed] on the second mora would incur a fatal violation of Dep[cl] or Integ[cl] (as in candidate (e, f) where the inserted instances of [closed] are circled).

Tableau 4.24 illustrates the diphthongization of [ɔɔ] to [ʊa].

Tableau 4.24

ɔɔ → ʊa	HiLeft	Pl→[cl]	Integ[cl]	Dep[cl]
a. ☞ ʊ a [cl] <[cor]> [cl]				*
b. ɔ a [cl] <[cor]>	*!			
c. ɔ æ [cl] [cor]	*!	*		
d. ʊ æ [cl] [cl] [cor]		*!		*
e. ʊ ɔ [cl] [cl] (cl)			*!	*
f. ʊ ɔ (cl) (cl) (cl)				**!*

As motivated in Cahill (1995, 1996a, b) and outlined above, Kɔnni exhibits [atr] harmony, described in terms of a constraint atrHarm. This constraint requires both moras in a domain to share an [atr] value. The constraint atrHarm interacts with the constraints atr→[cl] and HeightPl so that the long vowel /ee/ surfaces as [ie]. Satisfaction of atrHarm requires that the rightmost mora maintain its specification for [atr]. Pl→[cl] requires that the rightmost mora preserve its [closed] specifiction while HeightPl ensures that [coronal] is realized on this mora.

Tableau 4.25

ee → ie	atrHarm	HiLeft	Pl→[cl]	Integ[cl]	Dep[cl]
a. ☞ i e				*	*
b. i a	*!				*
c. e i		*!		*	*
d. i ɜ			*!		*

Candidate (a) in Tableau 4.25 violates Integ[cl] to place an occurrence of [closed] on each mora, and violates Dep[cl] to satisfy HiLeft. Candidate (b) satisfies Inget[cl] by singly linking the occurrence of [closed] from the input so that the second mora is low, but fails because it violates atrHarm. Candidate (c) creates an opening diphthongs thereby incurring a fatal HiLeft violation. Candidate (d) applies [atr] harmony to [a], but does not insert an instance of [closed] and incurring a Pl→[cl] violation. Another candidate in which [ATR] harmony applies and an instance of [closed] is inserted (creating a mid, central [ATR] vowel) is not as good as (a) since the candidate with a central vowel violates MAX[cor].

This section has provided an account of several languages exhibiting diphthongization whereby the height of one part of the input monophthong is manipulated. Most of the languages above display a shift of one degree. Eastern Finnish, for example, raises the first mora of long vowel so that /ee/ → [ie] while Southern Same lowers the second mora of a long vowel so that /ee/ → [eæ]. The stepwise nature of diphthongization in these attests to the continuous nature of vowel height. The Incremental Constriction Model is well adapted to analyze this phenomena since this model characterized vowel height as a single dimension. These languages receive a much complicated analysis in an approach using multiple features such as [high], [low], and [ATR] (Yip 1980).

At first glance, Kɔnni appears to be problematic for the Incremental Constriction Model since [−ATR] mid vowels surface as diphthongs in which both parts of the monophthong move in different directions, i.e., /εε/ → [ɪa] and /ɔɔ/ → [ʊa]. The account of Kɔnni above demonstrates that the "two" step change that [εε ɔɔ] undergo follows from the interaction of Integrity constraints and a constraint requiring the left half of Kɔnni diphthongs to be a high vowel.

4.2 The Phonological Status of "Low" Vowels

A long standing question in the phonology of vowel height concerns what constitutes a low vowel. It will be shown that languages may vary with respect to the number of vowel heights contrasted in even similar vowel inventories. Particular attention is paid to the status of the vowels [ε ɔ] since their characterization varies considerably in the phonological literature. In some cases, [ε ɔ] are contrasted with the feature [ATR] (or [RTR], [tense], etc.) so that these vowels are phonemically the same height as [e o]. In other treatments (e.g., Goad 1993), the vowels [ε ɔ] are specified as [low], and thus the same height as [a]. It will be shown that both representations are attested cross-linguistically, and that languages may differ in their representation for the vowels [ε ɔ] as determined by the system of contrasts in each language.

Three languages discussed above, Nzebi, Basaa (Chapter 3), and Efik (§4.3.3.1), have similar vowel inventories, all sharing the vowels [i e ε a ɔ o u]. The phonologies of these languages indicate that each language contrasts a distinct number of phonemic heights, and that the members of each height vary from language to language. Nzebi contrasts four heights, Basaá contrasts three heights, and Efik contrasts just two heights. In Nzebi, the vowel [a] is the unique low vowel. In Basaa, [ε a ɔ] are low. Efik contrasts two heights, one consists of the high vowels [i u] and the other consits of [e ε a ɔ o] all of which are contrasted by place features. In the Incremental Constriction Model, this is reflected in the vowel height specifications in (4.73).

(4.73)

a.				b.			c.	
Nzεbi				Basaa			Efik.	
iu	eəo	εɔ	a	iu	eo	εɔa	iu	eεaɔo
•	•	•		•	•		•	
•	•			•				
•								

As discussed in the previous chapter, Nzεbi (Guthrie 1968) exhibits stepwise raising whereby [a] raises to [ε], [ε ɔ] raise to [e o], and [e o] raise to [i u] as shown in (4.74). In the Incremental Constriction Model, these facts are accounted for as an assimilation for the

feature [closed] where each vowel acquires an additional specification for this feature, and therefore, surfaces as one step higher than its original (underlying) height. That is, the vowel [a], which is specified for no occurrences of [closed] underlyingly (4.73), gains one through height harmony and is incrementally raised to [ε]. The vowels [ε ɔ] are specified for one occurrence of [closed] underlyingly, and acquire a second through harmony to surface as [e o], and so on.

(4.74) Nzεbi Raising.

	normal	*raised*	*gloss*
e → i	bet	bit	'carry'
o → u	βoom	βuum	'breathe'
ə → i	kolən	kulin	'go down'
ε → e	suεm	suem	'hide oneself'
ɔ → o	tɔɔd	tood	'arrive'
a → ε	sal	sεl	'work'

The behavior of [a] versus [ε ɔ] demonstrates that the former contrasts with the latter in terms of height. If [a] and [ε ɔ] were the same height phonologically, one would expect them to behave the same with respect to harmony so that they would surface with the same heights. A unified treatment of the Nzεbi facts is possible only if [a] and [ε ɔ] have distinct height specifications.

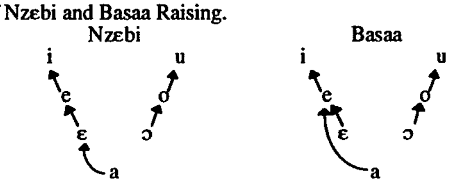
Basaá (Schmidt 1994) exhibits a similar stepwise raising process as shown below. The behavior of Basaa vowels with respect to raising suggests that the vowels [ε ɔ a] all constitute a single phonemic height.

(4.75) Basaa Raising.

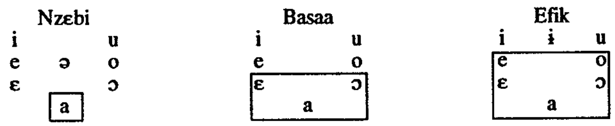
	normal	*raised*	*French gloss*	*English gloss*
e → i	seŋ	siŋ-il	'scrubber'	
o → u	top	tub-ul	'sing'	
ε → e	hεk	heg-el	'believe'	
ɔ → o	yɔŋ	yoŋ-ol	'learn'	
a → e	ɓak	ɓeg-el	'weave'	

The fact that /εa/ both emerge as [e] as a result of raising indicates that these vowels are the same height underlyingly. Both [a] and [ε] acquire the same feature through Raising, [closed], and both vowels surface with the same height, as [e]. A unified analysis of these facts is possible only if the two vowels share the same height underlyingly. Thus, Basaa contrasts only three heights (compared to four in Nzεbi), as [ε ɔ] are shown to have the same phonemic height as [a] (4.73).

(4.76) Effects of Nzεbi and Basaa Raising.



As demonstrated below, the contrast between [ε] versus [e] in Efik is characterized by a place feature, [pharyngeal] (cf. §4.3.3.1). Efik contrasts just two heights, one consisting of [i u] and the other of all remaining vowels ([e ɛ a ɔ o]). Thus, the vowel [a] has been shown to form its own phonological height in Nzɛbi, to form a single phonological height with [ɛ ɔ] in Basaa, and to form a single height with [e o ɛ ɔ] in Efik. In (4.77), the vowels of these three languages are depicted where a box is drawn around the vowels with which [a] forms a phonological height.

(4.77)


The phonologies of these languages determines what members of their vowel inventories are divided into heights. The display in (4.77) illustrates that what constitutes a "low" vowel varies from language to language, even among languages with essentially the same inventories.

4.3 Place Features and Vowel Height

In this section, the relation between the place feature [pharyngeal] and (phonetic) vowel height is examined.[39] First, the distinction between place and height features is discussed. Then a clear link is established between the vowel [a] and the feature [pharyngeal] drawing on evidence from Semitic and non-Semitic languages. In addition, evidence is presented that suggests that languages may distinguish upper and lower mid vowels, [e o] versus [ɛ ɔ], on the basis of a place feature. It is then argued that the feature [pharyngeal], which characterizes [a] may be extended to characterize other low vowels as well as including [ɛɔ]. On these grounds, the feature [pharyngeal] is argued to influence vowel height in that it may characterize low vowels.

4.3.1 The *Place* versus *Height* distinction

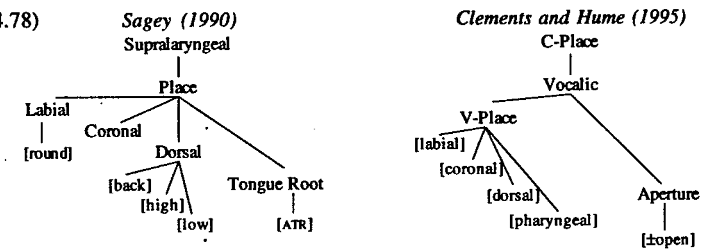
Before addressing the relationship between vowel place feature, and vowel height features, some discussion of feature organization is warranted. As discussed in Chapter 2, some models of feature organization recognize vowel features as an autonomous unit (e.g., Clements 1989, 1991; Odden 1991; Wiswall 1991; Clements and Hume 1995). In such models, a set of features that characterize either vowel place or vowel height are grouped into constituents. Other models do not recognize these constituents.

Feature constituents have traditionally been represented in terms of hierarchical "trees," as shown in (4.78) (Mohanan 1983, Mascaró 1983, Clements 1985, Sagey 1990). Representing constituents in terms of hierarchical graphs is called "feature geometry" following Clements (1985). In feature geometry, terminal features are dominated by organizing nodes. These nodes represent feature constituents, or groups of features that behave as a unit with respect to phonological processes. Sagey (1990) refers to these constituents as "natural classes."

[39] Two uses of 'height' are distinguished here. Phonological height refers to categories into which a grammar divides its inventory. Phonological height is distinct from phonetic height, which refers to the impressionistic quality of vowels without making reference to the phonemic system.

> [I]t has been proposed that phonological features be organized formally into classes of features analogous to the classes of segments defined by the phonological features. Given such formal classes of features, we can account for the fact that the groups of features that occur together in phonological rules are not random but are limited to certain recurring sets: rules that apply to more than one feature apply to a class label rather than to a list of features. This formal classification of phonological features will distinguish recurring sets of features... Thus, rules affecting place of articulation can refer to the class label "place of articulation," rather than each rule that affects place of articulation having to list all the place features individually (Sagey 1990:14).

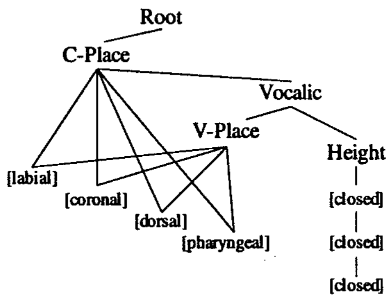
Sagey's (1990) natural classes of features are grouped into constituents represented by nodes. Nodes, in turn, may be dominated to represent larger constituents. The hierarchical nature of feature geometry can be thought of as the set and subset relation. The set of all features forms a constituent, and subsets of features constitute smaller constituents. Until very recently, the area of debate among researchers investigating feature constituency focused on which constituents should be recognized, and what the members of those constituent sets are (see, for example, Clements and Hume 1995 for arguments for a particular theory of constituents and members).

(4.78)


Of concern here are the vowel features. Sagey (1990) proposed the organization in (4.78) in which the vowel features (i.e., [round], [back], [high], [low], and [ATR]) are each dominated by the articulator (within the vocal tract) that is most directly involved in their production. Here, the feature [round] is beneath Labial since the lips are responsible for executing this feature. Similarly, the features [high], [low], and [ATR] are dominated by the Dorsal node since the tongue back is the point from which front vowels are distinguished from back vowels and high from low from the perspective of production.

The Clements and Hume (1995) organization in (4.78) groups all vowel features into a single set represented and dominated by the Vocalic node. Vocalic dominates two subordinate nodes, V-Place and Aperture (representing vowel height). Each of these nodes corresponds to sets of features that Clements and Hume argue form a natural class. The V-Place node comprises those features that characterize a vowel's color, for example. Their model predicts that languages should make reference to these two constituent sets (Clements and Hume 1995). In Chapter 2, languages were discussed that are analyzable only by recognizing these sets. In Kimatuumbi, for example, suffixes assimilate to the height of a stem vowel by are unaffected by that vowel's place. (For more exhaustive motivation for this separation, see, among others, Odden 1991, Clements 1991, Wiswall 1991). The Sagey (1990) model does not recognize the vowel height constituent since any node set containing vowel height features also includes some vowel place features. The node Dorsal, for example, dominates not only [high] and [low], but [ATR] as well. Likewise, Place dominates [high], [low], [ATR], but also doiminates [round] and [bask] as well.

(4.79) The Incremental Constriction Model.



In this section, the interaction of vowel place features and phonetic vowel height is examined. It is important to understand this to mean the possibility that members of the place constituent affect a vowel's quality along the hieght dimension. In the Incremental Constriction Model (4.79) (and Clements and Hume model in (4.78)), the place constituent comprises [labial], [coronal], [dorsal], and [pharyngeal]. Since the place and height constituents are not formally recognized in the Sagey model, the interaction of place features and vowel height is not an interesting issue in this model.

4.3.2 The Feature [pharyngeal] and *a*

The feature [pharyngeal] is widely used to characterize the low vowel [a]. McCarthy (1993) documents a number of cases from Semitic languages where [a] interacts with 'guttural' consonants. The consonants [q χ ʁ ħ ʕ h ʔ] are argued to form a natural class of 'gutturals' (Hayward and Hayward 1989, McCarthy 1991a) which interact with the vowel [a]. Hayward and Hayward propose that these sounds be characterized by the distinctive feature [pharyngeal] for the region in which these sounds are produced. On the same grounds, McCarthy (1991a) proposes for the feature [pharyngeal], which is currently widely adopted to define the natural class of [a χ ʁ ħ ʕ h ʔ].

McCarthy (1991a) successfully argues that the guttural consonants form a natural class, but defy characterization as such within traditional feature theory (e.g. Chomsky and Halle 1968, Sagey 1986). He demonstrates that gutturals act as a natural class with respect to cooccurrence constraints, as well as participation in a number of phonological processes.

The consonants [χ ʁ ħ ʕ h ʔ] cannot be charaterized in terms of any feature, nor combination of features, proposed in Chomsky and Halle (1968). Logical candidate features to define the gutturals are [back] and [low], but no combination of these features successfully delimits all and only the consonants in question. Among the gutturals, the uvulars [χʁ] are [−low] while the remainder are [+low] and the laryngeals [h ʔ] are [−back] while the remainder are [+back] (Hayward and Hawyard 1989, McCarthy 1991a).

Independent of the authors cited above, other authors have proposed that the low vowels be characterized in terms of a pharyngeal articulation. Wood (1979) characterizes

low vowels as [pharyngeal], as does Selkirk (1991). Clements (1991) uses [radical] (and later [pharyngeal]) to characterize [a] (see Clements and Hume 1995).

Evidence supporting the relationship between [a] and the guttural consonants is found in a range of languages. Among Semitic languages, vowels often assimilate to guttural consonants, surfacing as [a].

Semitic gutturals often exhibit a blocking effect whereby a rule of raising is blocked when the target vowel, [a], is near a guttural consonant. This is found in many Bedouin dialects of Arabic (e.g. Al-Mozainy 1981, Irshied 1984, Irshied and Kenstowicz 1984, McCarthy 1991a) In Rwaili Arabic (Prochazka 1988, Parkinson 1992), for example, a rule of dissimilation is blocked by an adjacent guttural. This process affects occurrences of [a] in open syllables whereby the left-most low vowel raises to [i]. Underlying /katab/ surfaces as [kitab] 'he wrote' (Parkinson 1992).

(4.80) Dissimilatory raising in Rwaili Arabic.

$$a \rightarrow i \,/\, \_\_ C\, a$$

/katab/	kitab	'he wrote'
/ðabaḥ/	ðibaḥ	'he killed'
/sakat/	sikat	'he stopped talking'
/sakatat/	skitat	'she stopped talking'

This process of Raising is formulated as a rule of dissimilation which breaks up sequences of [a]. Dissimilation is traditionally formalized as delinking in autosegmental phonology (Odden 1988), and so Rwaili Raising is formulated as in (4.81) where the feature [pharyngeal] is delinked from a open syllable's nucleus when followed by [a]. The delinking of the place feature pharyngeal results in a front vowel as [coronal] is the default[40] place for vowels (Hume 1994, Parkinson 1992).

(4.81)

```
      V              V
      ǂ              |
[pharyngeal]   [pharyngeal]
```

In optimality theory, GEN may perform an unlimited series of "procedures" on an input candidate so long as it is only evaluated at the end of all changes. Thus, the consecutive occurrences of [pharyngeal] on the vowel place tier incur an OCP (obligatory contour principle) violation (Leben 1980, McCarthy 1986, Odden 1988, and others). To avoid violating OCP, a candidate may delink one of the two occurrences of the offending features, or may delink the offending feature and replace it with another feature. When another feature is inserted, [cor] incurs the least serious markedness violation (Prince and Smolensky 1993, Hume 1994).

Tableau 4.26

katab → kitab	OCP	*[−cor]	*[cor]
a. ☞ i a / [cor] [ph]		*	*

[40] In some languages, dissimilatory delinking is not accompanied by the insertion of [coronal]. In Tigrinya (Buckley 1993), low vowels dissimilate but the delinked vowel surfaces as the central vowel [ɨ].

katab → kitab	Ocp	*[–cor]	*[cor]
b. a a [ph] [ph]	*!	**	
c. u a [lab] [ph]		**!	

All candidates in Tableau 4.26 incur one violation of *[–cor][41] since the second vowel in these candidates is specified as [pharyngeal] (where this constraint is evaluated only with respect to vowels). Candidate (c) incurs two violations of this constraint, however, because the feature [labial] is inserted on the first vowel. Candidate (b) also incurs two violations of *[–cor] since two [pharyngeal] specifications surface in this example. The Ocp is also violated by this candidate.

Raising does not apply, however, when the dissimilating vowel is adjacent to a guttural consonant. The examples in (4.82) show this effect as uvular, pharyngeal, and laryngeal consonants prevent the dissimilation from taking place when these consonants are next to the target vowel. Note also that the process is not inhibited by 'back' consonants since an adjacent velar consonant does not exhibit the blocking effect (cf. *kitab*).

(4.82) Raising Blocked by an Adjacent Guttural.

ṭbaχat	3fs	'cook'
naχal	3ms	'sift'
ʁasal	3ms	'catch'
ħazam	3ms	'milk'
ħafar	3ms	'dig'
ðbaħat	3fs	'kill'
gʕadat	3fs	'sit'
gaʕad	3ms	'sit'
hadaf	3ms	'return'

These facts are analyzed as a manifestation of the linking constraint (Hayes 1986, Schein and Steriade 1986), which prevents multiply linked structures from undergoing a process that targets singly linked elements (Parkinson 1992, McCarthy 1991a, Irshied and Kenstowicz 1984). In Rwaili, the dissimilation targets a single association line, that between [pharyngeal] and the target vowel. In the forms in (4.82), the feature [pharyngeal] is multiply linked to both the vowel and an adjacent consonant, thus blocking Raising (4.81). This analysis crucially depends upon the specification of the low vowel [a] for the feature [pharyngeal] (Parkinson 1992).

An alternative account would be to assume, as done in the analysis above, that the [pharyngeal] place of the vowel [a] and an adjacent guttural are fused. Thus, there is only a single occurrence of this feature multiply linked to both the vowel and the consonant. Thus, to delink this occurrence of [pharyngeal] would leave both the vowel and consonant unspecified. Whether a new place feature is filled in or not, this incurs an IdentC violation, a constraint that prohibits consonantal alternations.

[41] This constraint is taken directly from Prince and Smolensky (1993). It is not clear whether Prince and Smolensly posit the feature [coronal] to be binary or whether [–cor] is intended to represent "noncoronal."

Tableau 4.27

hadaf → hadaf	IdentC	Ocp	*[–cor]	Fill	*[cor]
a. ☞ h a a [ph] [ph]		*	*		
t i a [cor] [ph]	*!		*		*
p u a [lab] [ph]	*!		**		
□ □ a [ph]	*!			*	

Similar examples can be found in a non-Semitic language as well. Kera (Ebert 1974), a Chadic language spoken in southern Chad, for example, also exhibits a dissimilation of [a] that is blocked by adjacent laryngeals [h ʔ] (Kera has no other gutturals). In Kera, the vowel [a] becomes high, [ə] (equivalent to [ɨ] in IPA), when followed by a low vowel (Ebert 1974, Odden 1988). This is seen in (4.83).

(4.83) Kera raising.

/bal-a/	bəla	'like her'
/bal-an/	bəlan	'like me'
	ba	'not'
	pa	'again'
	bəpa	'no more'

The analysis of Kera is similar to that of Rwaili. Raising is a means of resolving an Ocp violation for the feature [pharyngeal]. The constraint IdentC blocks Raising when the target [a] is preceded by [h ʔ] since these consonants share a specification of [pharyngeal] with the target vowel. The blocking effect of the laryngeals is seen in the example *ham-am* 'eats you' in which raising does not apply (**həm-am*). The vowel [a] in Kera is a central vowel, which when raised is a high central vowel, [ə].

The behavior of [a] in both Rwaili Arabic and in Kera points to a relationship between the vowel [a] and the feature [pharyngeal]. This vowel shows an affinity for the guttural consonants, whether that set of consonants has many or two members. Since it is the feature [pharyngeal] that characterizes the guttural consonants (McCarthy 1991a), it must also be this feature that characterizes the vowel [a],[42] the vocalic member of the set of gutturals. The relationship between [a] and [pharyngeal] demonstrated, it will be shown in the following section that the place feature [pharyngeal] may characterize other vowels as well, and when it does, it has a "lowering" effect on that vowel.

[42] Some languages do not exhibit any evidence to suggest that [a] is specified as [pharyngeal], particularly languages that do not containt guttural consonants.

4.3.3 Place Features and the ɛ/e, ɔ/o contrast

In previous section, a relationship between the place feature [pharyngeal] and the vowel [a] was established. In this section, it will be shown that in some languages, the feature [pharyngeal] may characterize the vowels [ɛ ɔ] as well. An analysis of vowel harmony in Efik, Ngbaka, Bakwiri, and Bobangi supports this conclusion. Many authors have used the feature [ATR] to characterize this contrast ([pharyngeal] and [ATR] are often used interchangeably), but it is argued here that Efik harmony demonstrates that the feature (whether called [ATR] or [pharyngeal]) that characterizes the contrast between upper and lower mid vowels ([e o] vs. [ɛ ɔ]) is a place feature in some languages rather than a height feature[43] as is typically assumed (see, among many others, Odden 1991, Goad 1993, Casalli 1996). On this basis, it is argued that the place feature [pharyngeal] may characterize vowels other than [a], and that it has the phonetic effect of phonetically "lowering" vowels specified for this feature.

The languages discussed below exhibit phenomena that indicate that the contrast between the lower mid vowels [ɛ ɔ] and upper mid vowels [e o] is characterized by a place feature. (As discussed above, the term 'place feature' is taken to mean a feature dominated by the V-Place node in Clements and Hume 1995.) Assuming the organization of the Incremental Constriction Model (cf. §2.4, §4.3.1), for these languages the [ɛ ɔ] versus [e o] contrast must be characterized by one of the following features: [labial], [coronal], [dorsal], or [pharyngeal]. Based in part of the relationship established in the previous section between [a] and [pharyngeal], it is argued here that the place feature responsible for the [ɛ ɔ] / [e o] contrast is this feature.

4.3.3.1 Efik

This section describes a pattern of vowel alternations found in Efik, a Benue-Congo language[44] spoken in Nigeria. This language exhibits a place harmony in which all and only the place features assimilate. An analyisis of this harmony supports the separation of vowel features into Place and Height constituents (cf. §4.3.1). In addition, the place harmony in Efik argues that the distinctive pairs [ɛ] versus [e] and [ɔ] versus [o] contrast for a place feature, [pharyngeal]. While [pharyngeal] (or its equivalent [ATR]) has been used to characterize the contrast between [e o] versus [ɛ ɔ] elsewhere in the literature to account for languages such as Kimatuumbi with complete height harmony, an analysis of Efik demonstrates that this feature must be considered part of the place constituent.

Each of the vowels in (4.84) is contrastive, with the exception of [ɨ], which is derived from [i] as will be discussed below. While the vowel [e] never occurs in stems, this vowel is still distinctive as demonstrated by the minimal triplet ***ɛ́nɛ́k*** 'they dance,' ***ínɛ́k*** 'we dance,' and ***ɛ́nɛ́k*** 's/he dances.'

[43] The distinction between vowel height features and vowel place features is only significant in models that distribute vowel features among separate nodes that correspond to these constituents. In models (e.g., Sagey 1990) in which no special node is devoted to vowel place or vowel height there is no formal grounds on which to distinguish these sets of features.

[44]This variety of Efik is similar to that described in Cook (1986).

(4.84)

i	ɨ	u
e		o
ɛ		ɔ
	a	

The singular forms of the second and third person subject markers in Efik alternate in vowel quality as the examples below illustrate. The examples in (4.85) demonstrate that the quality of the second person singular (2s) and third person singular (3s) subject markers is entirely predictable from the following root vowel. These prefixes surface as a front vowel before front vowels, as in *ɛ-tɛm* 'you cook,' round before round vowels, as in *o-bom* 'you break,' and as [a] before a root containing this vowel, as in *a-tá* 'you chew.'

(4.85) Subject marking prefix alternations.

	'cook'	'chew'	'build'	'break'
1s	ń-tɛm	ń-tá	ḿ-bɔ́p	ḿ-bom
2s	ɛ-tɛm	a-tá	ɔ-bɔ́p	o-bom
3s	ɛ́-tɛm	á-tá	ɔ́-bɔ́p	ó-bom
1p	í-tɛm	í-tá	í-bɔ́p	í-bom
2p	e-tɛm	e-tá	e-bɔ́p	e-bom
3p	é-tɛm	é-tá	é-bɔ́p	é-bom

The alternation of the subject prefixes in (4.85) constitutes a process of harmony. This harmony constitutes a multiple feature assimilation since no single feature can account for the alternations seen in (4.85). If the harmony shown above were an assimilation for a single feature, e.g., [back], then it would be impossible for the prefix to reflect the [o] versus [ɔ] contrast in the stems seen in the examples *ɔbɔ́p* 'you (s) build' versus ***obom*** 'you (s) break.' Were the assimilation in (4.85) for just one feature [ATR] or [high], then the prefix could not reflect the front back contrast seen in ***ɛtɛm*** 'you (s) cook' versus ***ɔbɔ́p*** 'you (s) build.' The Efik harmony represents the simultaneous assimilation of several features.

The examples in (4.86) demonstrate that the harmonizing vowel does not assimilate to the height of the root vowel since in examples of the type *o-núk* 'you push' and *é-k͡pí* 's/he chops,' the prefix is not high, even when the trigger is a high vowel. The harmonizing prefixes do alternate before roots containing high vowels, but do not assimilate to their height.

(4.86) Prefix alternations before roots with high vowels.

	'chop'	'spread'	'see'	'push'
2s	e-k͡pí	e-brí	o-kút	o-núk
3s	é-k͡pí	é-brí	ó-kút	ó-núk

If the harmonizing prefix assimilated for all vowel features, the quality of the assimilating vowel would be identical to that of a following high vowel. An analysis in which only place features assimilate correctly predicts that the frontness and backness of the prefix vowel is identical to a following high vowels, but that their heights will differ. As seen in (4.87) the vowels [e o] appear before [i u] since these pairs differ only in terms of their specifications for height as seen in *ó-bom* 's/he breaks' and *ó-kút* 's/he sees.'

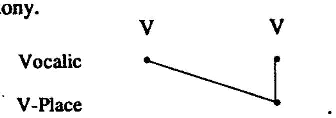
(4.87) Efik Harmony.

$$\text{the harmonizing prefix} \rightarrow \left\{\begin{array}{c} \text{e} \\ \text{o} \\ \text{o} \\ \text{ɛ} \\ \text{ɔ} \\ \text{a} \end{array}\right\} \text{ before } \left\{\begin{array}{c} \text{i} \\ \text{u} \\ \text{o} \\ \text{ɛ} \\ \text{ɔ} \\ \text{a} \end{array}\right\}$$

The harmony discussed above involves an assimilation for all place features, but no height features. This process, Place Harmony, makes crucial reference to the Place constituent, since it is just this set of features for which the harmonizing vowel assimilates. In a feature organization in which Place and Height features are not distinguished, no straightforward account of the Efik facts is possible (cf. Chapter 2).

The result of place harmony yields a V-Place node that is multiply linked between a root vowel and a prefix vowel. In this way, the harmonizing prefix will have identical place features as the folloing root vowel, but may differ in height. The constraint motivating this multiple linking is described below.

(4.88) Result of Place Harmony.



Having established that Place Harmony involves the simultaneous assimilation of all place features to the exclusion of any height features, some discussion of the specification of vowels in Efik is in order. The examples in (4.89) demonstrate that the contrast between upper and lower mid vowels that exists in roots, e.g., *tó* 'come from' versus *tɔ́* 'plant,' is preserved in the harmonizing prefixes. This fact is illustrated with verbs that contrast for mid back vowels since the vowel [e] is absent in stems though examples such as *ɛ́-dɛ́* 's/he sleeps' versus *é-dí* 's/he comes' indicate that the contrast is maintained for front vowels as well.

(4.89) Mid vowel contrasts and Place Harmony.

ɔ-tɔ́	'you (s) plant'	o-tó	'you (s) come from'
ɔ́-tɔ́	's/he plants'	ó-tó	's/he comes from'
ɔ-wɔ́k	'you (s) swim'	o-bom	'you (s) break'
ɔ́-wɔ́ŋ	's/he drinks'	ó-kop	's/he hears'
ɔ́-kwɔ̂	's/he sings'	ó-bo	's/he takes'

Since the harmonizing prefix assimilates for place features but not height features, the feature that characterizes the contrast between [ɛ] versus [e] and [ɔ] versus [o] must be a place feature (4.89). The feature [pharyngeal] (or [–ATR]) has been established to affect vowel height (cf. §4.3.2), and is argued to do so in Efik as well (Parkinson 1993). The feature [pharyngeal] characterizes the lower mid vowels [ɛ ɔ] but not the upper mid vowels [e o] as in (4.90).

(4.90) Efik vowel specifications.

	i	ɨ	u	e	o	ɛ	ɔ	a
[coronal]	•			•		•		
[labial]			•		•		•	
[pharyngeal]						•	•	•
[closed]	•	•	•					

The feature [coronal] characterizes front vowels while [labial] characterizes round vowels.[45] The high vowels [i ɨ u] are characterized by the feature [closed]. Recall that the high vowels and upper mid vowels behave identically as triggers of harmony since the alternating prefix surfaces with the same quality before [u] as before [o] (cf. *okút* 'you (s) see' versus *obom* 'you break'). The specifications above correctly predict that Place Harmony (4.88) will spread the feature that characterizes the opposition between [ɛ ɔ] and [e o] but not the feature that distinguishes [e] from [i] nor [o] from [u].

In the examples above, the quality of the vowel in the harmonizing prefixes is unclear, since it reflects the quality of the following vowel. An examination of the negative marker *kɛ* reveals that the harmonizing vowel surfaces as [ɛ] in cases where there is no vowel to which it may assimilate. The negative marker *kɛ* surfaces as such phrase finally, but alternates when it precedes a verb root. In negatives, *kɛ* is suffixed to a verb to mark negation so that *ń-nɛ́k* 'I dance' contrasts with *ń-nɛ́k-kɛ́* 'I don't dance.' More examples of the negative suffix are provided below.

(4.91) Negative suffix *kɛ*.

ú-nɛ́k	'you dance'	ú-nɛ́k-kɛ́	'you are not dancing'
ú-saŋá	'you walk'	ú-saŋá-kɛ́	'you are not walking'
í-dɔk	'we dig'	í-dɔk-kɛ́	'we are not digging'
ɛ́-tɛ́m	's/he weeds'	í-tɛ́m-kɛ́	's/he is not weeding'

The negative marker also appears in the negative focus tense, as seen in the negative focus forms for 'to cook' below. This tense is formed by prefixing a subject marker to the root, and suffixing the negative marker *kɛ* and a reduplicant of the root.[46] In this tense, *kɛ* appears before the verb root, so that harmony may apply.

(4.92) Negative focus tense: the verb tɛm 'cook.'.

sub-root-kɛ́-reduplicant	
ń-tɛm-kɛ́-tɛm	'I am not *cooking*'
ú-tɛm-kɛ́-tɛm	'you (s) not *cooking*'
í-tɛm-kɛ́-tɛm	's/he is not *cooking*'
í-tɛm-kɛ́-tɛm	'we are not *cooking*'
í-tɛm-kɛ́-tɛm	'you (p) are not *cooking*'
í-tɛm-kɛ́-tɛm	'they not *cooking*'

In the examples in (4.93), the quality of the vowel in the negative marker alternates, reflecting the quality of the following vowel. The forms in (4.93.a) demonstrate that the

[45] This analysis does not crucially depend on the selection of [labial] over [dorsal] for the vowels *u o ɔ*.

[46] The analysis of Place Harmony in this tense does not crucially hinge on the posited structure of the verb root on the left, followed by *kɛ* and the reduplicant. The alternative in which the reduplicant is on the left, followed by *kɛ* and the root seem unlikely since this would then be the only construction in Efik where the negative marker is a prefix.

negative marking suffix undergoes Place Harmony, triggered by the reduplicant. As expected with Place Harmony, the negative marker never surfaces as a high vowel, even when concatenated to a root with a high vowel (4.93.b).

(4.93) Place harmony in the negative focus tense.

a.	ń-tabi-ká-tabi	'I am not *tasting*'
	ú-brɛ-kɛ́-brɛ́	'you (s) are not *playing*'
	ŋ́-kprák-ká-kprák	'I am not *becoming restless*'
	ú-fɛrɛ́-kɛ́-fɛrɛ́	'you are not *running*'
	ì-dɛ-kɛ́-dɛ	's/he is not *sleeping*'
	ń-kɛrɛ-kɛ́-kɛrɛ	'I am not *thinking*'
	ì-kot-kó-kot	's/he is not *seeing*'
	ì-wap-ká-wap	's/he is not *tearing*'
	ì-taǎa-ká-taǎa	's/he is not *chewing*'
b.	ḿ-bri-kɛ́-brí	'I am not *spreading*'
	ḿ-fri-kɛ́-fri	'I am not *blowing*'
	ú-nuk-kó-nuk	'you are not *pushing*'
	ì-wut-kó-wut	's/he is not *showing*'

The negative particle normally appears stem finally, and surfaces as *kɛ*. The fact that it harmonizes with the root vowel in the examples in (4.92) and (4.93), establishes that Place Harmony targets the vowel (that surfaces as) [ɛ]. Verbs like *í-tá* 'we chew,' *ú-saŋá* 'you walk,' and *é-bɔp* 's/he builds' show that the vowels [i u e] do not assimilate to the following root vowel, and cannot be the target of Place Harmony[47].

The behavior of the negative suffix *kɛ* phrase finally (4.91) compared with the examples in (4.93) demonstrates that the harmonizing vowel surfaces as [ɛ] when it does not appear in a harmonizing environment. Based on the specifications in (4.90), Place Harmony is described in terms of a constraint that requires the alignment of all V-Place features leftward from a stem vowel to the harmonizing prefix.

(4.94) AlignV-Place.

ALIGNVPL = the vowel place features of a stem vowel are aligned to the left edge of the word.

The fact that only [ɛ] undergoes place harmony in Efik is attributed to the interaction of the alignment constraint (4.94) and a set of identity constraints. These identity constraints ensure that a vowel in the output has the same quality (i.e., feature specifications) as its input correspondent. The identity constraints that require, for example, /o/ to surface as [o] are abbreviated as IDENT-o. The identity constraints for each vowel in the Efik inventory are ranked as in (4.94).

(4.95) IDENT-i, IDENT-e, IDENT-ɨ, IDENTu, IDENT-o, IDENT-ɔ, IDENT-a » IDENT-ɛ

This ranking allows the alignment constraint in (4.94) to be ranked above IDENT-ɛ, but lower than the identity constraints of all other vowels (4.96). In this way, only candidates with the input /ɛ/ will satisfy ALIGNVPL. For candidates with all other input vowels in the

47 The vowels [a o ɔ] do not occur in prefixes (except via harmony) and it is, therefore, impossible to demonstrate that these vowels do not undergo harmony.

prefix, the violation of identity constraints is more serous than the misalignment of V-Place so that these vowels do not harmonize.

(4.96) IDENT-V» ALIGNVPL » IDENT-ɛ

The interaction of these constraints is shown in the following tableaux. For an input such as /ɛ-bu/, satisfaction of ALIGNVPL violates the lower ranked IDENT-ɛ.

Tableau 4.28

ɛ-bu → o-bu	IDENT-V	ALIGNVPL	IDENT-ɛ
a. ☞ o u <VPL> VPL			*
ɛ u VPL VPL		*!	

For inputs with prfixes containing any other vowel, the identity constraints for that vowel outrank ALIGNVPL, and so, no multiple linking takes place.

Tableau 4.29

e-bu → e-bu	IDENT-V	ALIGNVPL	IDENT-ɛ
a. ☞ e u VPL VPL		*	
o u <VPL> VPL	*!		

The forms in (4.97) show that Place Harmony applies across [ɨ] since the harmonizing vowel assimilates to the second root vowel, rather than [ɨ], for these roots. In forms like *átɨčá* 's/he kicks' (from /ɛ́-tɨčá/) it is clear that the harmonizing vowel assimilates to [a] while the verb *e-yɨbí* you (s) flog,' shows that only place features assimilate, indicating that the process is Place Harmony as described above.

(4.97) Place Harmony applies across *ɨ*.

ɛ-sɨbě	'you (s) slice'
e-yɨbi	'you (s) flog'
á-tɨčá	's/he kicks'
ɔ́-kɨbɔ́	's/he crouches'
á-fɨná	'you (s) annoy'
ɛ́-tɛ́-tɨbɛ́	's/he is *smelling*'
ɔ-kɔ́-kɨbɔ́	'you (s) are *crouching*'
á-tá-tɨčá	'you (s) are *kicking*'

The vowel [ɨ] does not undergo the process of Place Harmony nor does it block its application. Instead, harmony applies across [ɨ]. Since Place Harmony is defined as the regressive spreading of the V-Place node, the transparency of [ɨ] indicates that this vowel lacks a V-Place node. An examination of the occurrence of this vowel confirms this analysis.

All surface occurrences of [ɨ] are derived from /i/. When underlying /i/ occurs between consonants within the root, it surfaces as [ɨ], a high central vowel that is specified for [high] but lacks a place specification as noted in (4.90). This alternation is shown in the comparison of *é-tí* 's/he remembers' and *é-tɨ́-ɔ́í* 's/he does not remember,' where the root vowel of the stem 'to remember' is shown to be /i/, but the suffixation of the negative particle *kɛ́* places the root vowel [i] in an inter-consonantal environment, where it surfaces as [ɨ].

The alternation of /i/ to [ɨ] is accounted for by the constraint CENTRALIZE, which prohibits the cooccurrence of the features [closed] and [coronal] intervocalically. Candidates in which [i] loses its specification result in a central vowel as expected from the specifications in (4.90). Positing high, central vowels as placeless follows the work of Clements (1991:2).

(4.98) Centralize.

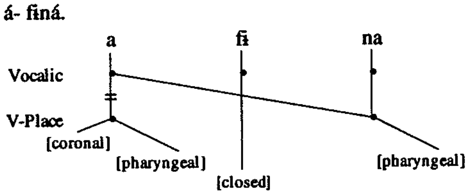
CENT = the vowel [i] is prohibited interconsonantally.

Efik contrasts just two phonemic vowel heights, high and non-high where the former is characterized by a single occurrence of the feature [closed] in the Incremental Constriction Model and the latter is specified for no occurrences of [closed].

With the placelessness of [ɨ] established, an analysis of its transparency is straightforward. Since Efik Place Harmony is an assimilation for all place features, the placeless vowel [ɨ] clearly cannot trigger the process. The forms in (4.97), however, demonstrate that [ɨ] is transparent to Place Harmony as well.

Odden (1994) proposes a detailed theory of transparency and opacity in which assimilations must spread elements that are "local." With respect to transparency, he argues that transparent vowels are not specified for the harmonizing element (Odden 1994:311). In the case of /ɛ́-fìná/ → *á-fɨná* 'you (s) annoy,' the prefix harmonizes across an intervening [ɨ] with a following [a].

(4.99) /ɛ́-finá/ → á- fɨná.



An analysis in which Efik harmony is described in terms of the V-Place constituent is consistent with the account given for the transparency of [ɨ]. If [ɨ] has no V-Place features, then it cannot be a trigger to Place harmony, nor is it predicted to block Place harmony (Odden 1994). An analysis in which Efik harmony is described in terms of the entire Vocalic constituent, with intervening constraints prohibiting the spreading of [closed] renders the transparency of [ɨ] anamolous. In this case, the vowel [ɨ], which is specified for some features (namely, [closed]), should trigger a total harmony, and should be opaque to total harmony as well. Thus, the analysis of Efik harmony demonstrates that this is an assimilation only for V-Place. Therefore, since the contrast between upper and lower mid vowels is maintained in the harmonizing context, the contrast between [e] and [ɛ] as well as [o] and [ɔ] must be a V-Place feature.

4.3.3.2 Ngbaka

Ngbaka (Thomas 1963, 1970) is a language spoken in the Central African Republic that exhibits a widely discussed process of vowel harmony (Wescott 1965, Chomsky and Halle 1968:359, Clements 1982, Churma 1984, 1994, Mester 1986, Steriade 1987, McCarthy 1991, Archangeli and Pullyblank 1994, and Parkinson 1995). Ngbaka contrasts the vowels in (4.100).

(4.100) Ngbaka vowels.

i		u
e		o
ɛ		ɔ
	a	

Thomas (1963) describes a set of *incompatibilités* that characterize the fact that all the vowels in (4.100) do not freely cooccur in Ngbaka. Generally, while any vowel may cooccur with itself (4.101.a), vowels of the same height (but different place) may not cooccur. Thus, *siki* and *suku* are permitted, **siku* and **suki* are unattested. Vowels of differing heights are attested as seen below where high and low vowels cooccur (4.101.b), and mid and low vowels cooccur (4.101.c).

(4.101) Attested roots in Ngbaka.

a.	siki	'island'	bili	'work'
	bulu	'threshold'	putu	'crumb'
	sek͡pe	'basket'	mbele	'pâte'
	ʔobo	'lie'	koto	'wallet'
	tɛmɛ	'stone'	yɛŋgɛ	'sieve'
	kɔpɔ	'discussion'	dɔpɔ	'axe'
	bala	'reunion'	kata	'iron'
b.	zimba	'to look for'	nzambu	'palm nut pulp'
	pɛpu	'wind'	zozi	'judge'
	zedi	'Thursday'		
c.	kalɔ	'dog'	wagɛ	'yam'
	kalo	'proclamation'	yaboo	'group, together'
	nzale	'buffalo'	gazɔ	'ankle bell'
	ndeya	'scorpion'	sɔya	'kind of banana'

In addition, upper mid vowels [e o] cannot cooccur with lower mid vowels [ɛ ɔ] so that *zozi*, *kalo* and *kalɔ* are permitted, but **kɛlo* is unattested. Finally, different round vowels may not cooccur, allowing *kɔpɔ* but not **kupɔ*.

(4.102) Incompatabilités from Thomas.

a. Vowels of the same height may not cooccur.
b. Upper mid vowels and lower mid vowels may not cooccur.
c. Round vowels may not cooccur.

Thomas (1963:62) accounts for the gaps described in (4.102) with a process of vowel harmony, the effects of which are to allow the combinations in (4.101) above, and rule out those shown below in (4.103).

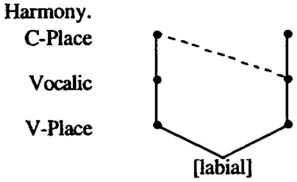
(4.103) Unattested roots.

*CiCu	*CuCi
*CeCo	*CoCe
*CɛCɔ	*CɔCɛ

Ngbaka rules out sequences like those found in (4.103) with a harmony process that forces a vowel to assimilate to another for place if both vowels are of the same height. Ngbaka rules out unlike round vowels sequences (4.102.c) with another harmony process in which a vowel assimilates to another for height if both are round. Harmonies that apply only between segments that share a specification for some feature are called parasitic in Cole (1987). Ngbaka Harmony in Ngbaka is parasitic since a vowels only assimilates for place if they are of the same height, or for height if they are both round.

Cole (1987, see also Cole and Trigo 1988) formalizes parasitic harmonies as spreading between two segments that are multiply linked for the feature that they must have in common for the assimilation to take place. In the case of Ngbaka, a vowel assimilates to another for height if both are round. This process is called Round-Dependent Harmony and is formalized in (4.104) as spreading the V-Place node between two vowels that share a Height node.

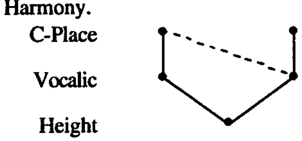
(4.104) Round-Dependent Harmony.



The process of Round-Dependent harmony eliminates sequences of vowels that are both round, but differ in height (4.102.c). If a sequence of unlike round vowels were to occur in Ngbaka, Round-Dependent Harmony would ensure that both vowels surfaced as identical, i.e., **bolu* → *bulu*.

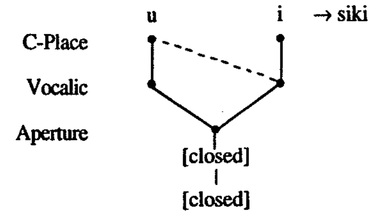
Ngbaka also rules out sequences of different vowels of the same height. The harmony that accounts for these gaps is called Height-Dependent Harmony, which assimilates two vowels that are of the same height, but different place. This parasitic harmony is formalized as in (4.105) where the Vocalic node is spread from one vowel to another that shares the Height node.

(4.105) Height-Dependent Harmony.



The harmony process in (4.105) eliminates sequences such as **suki* and derives *siki* as shown below.

(4.106) **suki* → *siki*.



Ngbaka also disprefers sequences of upper mid-vowels [e o] and lower mid-vowels [ɛ ɔ] so that the roots in (4.107) are also unattested. Ruling out such combinations is straightforward if the upper and lower mid vowels constitute a single phonological height, and are contrasted with a place, rather than a height, feature. In this case, the roots in (4.107) would undergo Height-Dependent Harmony (4.105) and surface as a sequence of identical vowels.

(4.107) Unattested mid-vowel roots.

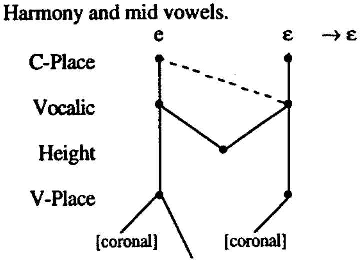
*CeCɔ	*CɔCe
*CeCɛ	*CɛCe
*CɛCo	*CoCɛ
*CoCɔ	*CɔCo

Such an analysis of Ngbaka is argued for here (and in Parkinson 1995). The vowels *ɛ* versus *e* and *ɔ* versus *o* are distinguished on the basis of a place feature, so that these vowels, [e ɛ o ɔ], form a single phonemic height. As the place feature [pharyngeal] is related to vowel height (cf. §4.3.2–4.3.3), it is argued here that this feature characterizes the opposition between [ɛ ɔ] and [e o] such that [ɛ ɔ] are specified for this feature, and [e o] are not.

(4.108) Specification of Ngbaka vowels.

	i	u	e	o	ɛ	ɔ	a
coronal	•		•		•		
labial		•		•		•	
pharyngeal					•	•	•
closed	•	•	•	•	•	•	
closed	•	•					

(4.109) Height-Dependent Harmony and mid vowels.



[pharyngeal]

4.4 Summary

This chapter has addressed several issues concerning vowel height. The treatment of low vowels crosslinguistically was examined, showing that languages may vary with respect to which (and how many) vowels combine with [a] to form a single vowel height. The relationship between place features and phonetic height was investigated showing that some languages contrast more than one front (or back) vowel of a single height in which case the feature [pharyngeal] or [ATR] may distinguish [ɛ] from [e] or [ɔ] from [o]. The processes of complete height harmony, coalescence, and diphthongization were studied, showing that an account of these phenomena is possible within the Incremental Constriction Model.

CHAPTER 5

HEIGHT ALTERNATIONS IN KIKURIA

5.0 Introduction

This chapter undertakes an examination of vowel height alternations in Kikuria (Chacha and Odden 1994, Cammenga 1994, Parkinson 1994), a Bantu language spoken in Kenya and Tanzania. Kikuria exhibits partial height harmony in addition to complete height harmonies, and vowel coalescence. The analysis of these facts is provided using the Incremental Constriction Model to describe vowel height, within the constraint-based framework of optimality theory. Partial Height harmony is discussed in §5.1. The processes of complete height harmony are discussed in §5.2. Coalescence is described in §5.2.3. Finally, the interaction of these processes is addressed in §5.3.

The dialect discussed in Chacha and Odden (1994) differs slightly from that in Cammenga (1994). These differences will be noted where relevant. The examples are from Chacha and Odden (1994) unless othwise indicated.

(5.1) Kikuria vowels.

i		u
e		o
ɛ		ɔ
	a	

Kikuria contrasts the vowels in (5.1). For expository purposes, the vowels [e ɛ ɔ o] are referred to here as *mid vowels* while the vowels [e o] are *upper-mid* vowels and [ɛ ɔ] are *lower mid* vowels.

(5.2) Kikuria vowel specifications.

	i	u	e	o	ɛ	ɔ	a
[coronal]	•		•		•		
[labial]		•		•		•	
[closed]	•	•	•	•	•	•	
[closed]	•	•	•	•			
[closed]	•	•					

Within the Incremental Constriction Model, Kikuria high vowels are specifed for three occurrences of [closed], the upper mid vowels are specified for two occurrences of [closed], the lower mid vowels are specified for one occurrence of [closed], and the low vowel [a] is specified for no occurrences of this feature.

5.1 Partial Height Harmony

Kikuria exhibits a process of partial height harmony by which the mid vowels [e ɛ ɔ o] are raised one step before a high vowel. This process can be seen to apply to verbs where a high vowel in a suffix triggers raising of a root containing a mid vowel. In the examples in (5.3), the root vowels in the infinitive are unchanged, but surface as one step higher in the causative, or before the suffix that derives nouns from verbs.

(5.3) Partial height harmony in Kikuria.

	infinitive	*causative* *-i*	*agent nominalization* *-i*	*gloss*
a.	oko-rɔ́g-a	oko-róg-y-a	omo-róg-i	'witch'
	oko-gɔ́ɔ́gá	oko-góóg-y-á		'slaughter'
	oko-gɔ́ɔ́t-á	oko-góót-y-á	omo-góót-i	'hold'
	ogo-tɛ́rɛ́k-a	ogo-térék-y-ǎ	omo-térék-i	'brew'
	oko-gɛ́s-a	oko-gés-y-á	omo-gés-i	'harvest'
	ogo-tɛ́ɛ́m-á	ogo-téém-y-á	omo-téém-i	'hunt mushrooms'
b.	oko-sóók-á		umu-súúk-i	'respect'
	oko-hóór-a		umu-húúr-i	'thresh'
	ogo-táčór-a		omo-táčúr-i	'untie'
	oko-rém-a		umu-rím-i	'cultivate'
	ogo-tégét-ǎ		umu-tígít-i	'be late'

The roots in (5.3.a) contain lower mid vowels (in the infinitive) while those in (5.3.b) contain upper mid vowels.[48] The causative suffix, [-i], surfaces as a glide in these examples due to the independent process of glide formation.[49] Examples such as /okotɛ́rɛ́ki/ → *ogotéréki*[50] 'brewer' and /okotégétia/ → *ugutígítyǎ* 'to cause to be late' illustrate that the process applies across the board to all mid vowels in a root. Examples such as *obo-téẽndéér-u* 'slipperiness' (cf. *obotérɛ*, from Cammenga 1994) illlustrate that partial height harmony is triggered by [u] as well as by [i].

Partial height harmony is also found to apply to prefixes as seen in the examples in (5.4). Noun class prefixes containing mid vowels undergo partial height harmony when followed by a root with a high vowel. In the examples below, a stem without a high vowel

48 Chacha and Odden (1994) differ from Cammenga (1994) on their analyses of these facts. While Cammenga treats the alternations in (5.3.a, b) as single process, Chacha and Odden analyze the raising of lower mid vowels and the raising of upper mid vowels as distinct processes. Chacha and Odden (1994:9) take this position, in part because the negative infinitive prefix *tɔ́kó* changes to *tɔ́kú* before a high vowel and not **tókú*. In addtion, the palatal nasal [ɲ] and glides trigger the raising of [e o] but not of [ɛ ɔ].

49 See Chacha and Odden (1994) for tonal arguments supporting the analysis of the causative suffix as a vowel underlyingly. See Odden (1987) and Cammenga (1994) for an analysis of the tone system of Kikuria

50 As in many Bantu languages, Dahl's law voices the [k] of a prefix before root begining with a voiceless obstrent.

is provided to show the quality of the prefix outside of the harmony environment and then again before a root with a high vowel. (The number of the noun class prefix follows the nouns, the infinitives are followed by INF.)

(5.4) Partial height harmony in prefixes.

unraised		*raised*		*class*
omo-sááčá	'male'	ụmụ-rííisya	'boy'	1
omo-góóndo	'plowed field'	ụmụ-sí	'sugar cane'	3
eme-té	'trees'	ịmị-sí	'sugar canes'	4
e-séésé	'dog'	ị-tííɲi	'animal'	9
oro-gɛ́na	'grinding stone'	ụrụ-síri	'rope	11
oro-tárɛ	'stone'	ụrụ-gúta	'wall'	11
ogo-táángá	'to begin'	ụgụ-sííká	'to close a door'	INF
oko-réma	'to plow'	ụgụ-túúhá	'to be blunt'	INF

The lower mid vowels do not appear in prefixes (with one exception, see footnote 48) so that examples in which prefixal [ɛ ɔ] raise cannot be provided. Chacha and Odden (1994) provide further examples demonstrating that subject and object prefixes also undergo raising when followed by a high vowel. In examples containing a prefix with a mid vowel, a root with a mid vowel, and a high vowel suffix, both the root vowels and the prefix vowels undergo the process.

(5.5)

	underlying		*surface*	*gloss*
a.	omo-rém-i	→	ụmụ-rị́m-i	'farmer'
	omo-sóók-i	→	ụmụ-súụ́k-i	'one who respects'
	omo-héétók-i	→	ụmụ-hị́ị́tụ́k-i	'one who remembers'
b.	omo-táčór-i	→	omo-táčụ́r-i	'one who unties'
c.	omo-rɔ́g-i	→	omo-rọ́g-i	'witch'
	omo-tɛ́rɛ́k-i	→	omo-tẹ́rẹ́k-i	'brewer'

Both prefix vowels and both root vowels are raised before the agentive suffix [-i] in *umuhíítúki* 'one who remembers' (cf. *okohéétóká* 'to remember'). Partial height harmony, then, applies to all the mid vowels of a root. Notice, however, that the low vowel [a] blocks the process. In (5.5.b), harmony applies to the second stem vowel, /o/, raising it to [u], but the first stem vowel [a] does not undergo the assimilation. The nonparticipation of [a] in the root explains why the prefix vowels do not raise in *omo-táčúri* 'one who unties.'

The prefix vowels do not raise in (5.5.c) either, though the lower mid vowel of these roots do undergo harmony (cf. *oko-rɔ́ga* 'to bewitch'). The Dominance/Precedence prohibition (cf. §3.1.2) prevents an instance of [closed] from spreading from one vowel to another where both vowels are specified for the same number of occurrences of [closed].

Partial height harmony in Kikuria is described as an assimilation by which mid vowels increase their number of [closed] specifications by one. This harmony is motivated by an alignment constraint.

(5.6) Align([closed]max, L, Word, L)

Align[cl] = for all vowels specified for the maximum number of occurrences of [closed] there exisits an occurrence of [closed] such that the left edge of that feature and the left edge of the word coincide.

As the vowel [a] blocks harmony, ALIGN[cl] is partially violated in the optimal candidate, (a) in Tableau 5.1. The winning candidate incurs one violation of ALIGN[cl] for the vowel [a], and two more for each of the unassimilated prefix vowels. The losing candidates, (c–e), incur fewer violations of ALIGN[cl] by linking [closed] to the input vowel [a], each time violating a higher constraint. Even for candidates in which [a] undergoes partial height harmony, the prefix vowels cannont assimilate in accordance with the Dominance/Precedence prohibition. Candidate (b) fails to multiply link an occurrence of [closed] from the high vowel suffix, thereby incurring an ALIGN[cl] violation for each stem vowel. The forth violation of this candidate makes it less good than (a).

Tableau 5.1

omo-táčór-i → omotáčúri	HEIGHTPL	Ident[dor] IDENT[lab]	ALIGN[cl]
a. o o á ú i ☞ [cl]			***
b. o o á ó i [cl]			****!
c. o o έ ú i [cor] [cl]		*!	**
d. o o ɔ́ ú i [dor] [cl]		*!	**
e. o o ɔ́ ú i [cl]	*!		**

The constraint NOGAP is ranked above ALIGN[cl] as shown in Tableau 5.2.

Tableau 5.2

omo-táčór-i → omotáčúri	NOGAP	ALIGN[cl]
a. o o á ú i ☞ [cl]		***
b. u u á ú i [cl]	*!	

(5.7) NOGAP, HEIGHTPL, IDENT[dor], IDENT[cor] » ALIGN[cl]

The process of partial height harmony in Kikuria suggests that the ranking in (5.7) holds of that language.

5.2 Complete Height Harmony

Kikuria exhibits two processes of complete height harmony. In one, high vowels are lowered to [e o] before upper mid vowels. In the other, upper mid vowels are lowered to [ε ɔ] after lower mid vowels.. In each case, the target vowels are lowered to the exact height of the trigger. Following Odden (1991), Clements (1989, 1991), and others, complete height assimilation is formalized as a simultaneous assimilation for all members of the Height constituent, expressed as an assimilation for the height node.

5.2.1 High vowel lowering

High vowels are lowered to [e o] when followed by these vowels. While prefixes do not undergo the process, high vowels in roots do lower when followed by suffixes containing [e o]. Examples of High Vowel Lowering are provided in (5.8) below. The applied suffix *-er*, the stative suffix *-ok*, and the reversive suffix *-or* all trigger the harmony.

(5.8) High vowel lowering.

ogo-séék-ér-á	'to close for'	ugu-síík-á	'to close'
oko-róg-ér-ǎ	'to cook for'	uku-rúg-a	'to cook'
oko-hót-ók-ǎ	'to disappear by rubbing'	uku-hút-a	'to rub oof'
oko-réb-ór-ǎ	'to unblock'	uku-ríb-a	'to block'
ogo-tók-ór-ǎ	'to dig up'	ugu-túk-a	'to dig'

Note that while the height of infinitival prefix vowels varies in the examples in (5.8), this alternation is the result of the application (and non-application) of partial height harmony. High vowel lowering bleeds partial height harmony. For example, in *ugu-siik-a* 'to close,' the prefix vowels of /oko/ are raised as a result of partial height harmony. In the example *oko-seek-er-a* 'to close for,' the suffix vowel of the applied suffix [er] triggers the lowering of the stem vowel, thus removing the trigger for partial height harmony.

High vowel lowering is described in terms of an alignment constraint. This constraint requires that the height node be aligned to the left edge of the stem.

(5.9) ALIGN(Height Suffix, L, Stem, L).

ALIGNHTL = For all vowels specified for [closed], there exists a Height node such that the Left edge of Height and the Left edge of the stem coincide.

Satisfaction of ALIGNHTL results in a violation of the lower ranked constraint IDENT[cl].

Tableau 5.3

-síík-ér- → séék-ér	ALIGNHTL	IDENT[cl]
a. éé é ☞ <HT> HT		*
b. íí é HT HT	*!	

Examples such as *ogo-sár-ék-ǎ* 'to be destroyed' demonstrate that High vowel lowering does not apply to [a]. Failure to multiply link the Height node of the suffix vowel to a root containing [a] does not incur a violation of AlignHtL, as defined in (5.8).

Tableau 5.4

-sár-ék- → -sár-ék	AlignHtL	Ident[cl]
a. ☞ á é / Ht Ht		
b. ɜ́ é / <Ht> Ht		*!

AlignHtL is defined such that a Height node is aligned leftward to the edge of the stem. This accounts for the fact that prefix vowels do not undergo High Vowel Lowering, as the example *ibi-té* 'chairs' illustrates.

ibi-té → ibi-té	AlignHtL	IdentV
a. ☞ i i e / Ht Ht Ht		
b. e e e / <Ht> <Ht> Ht		*!*

Since AlignHt L is satisfied by both candidates, i.e., candidate (b) does not violate alignment as defined for the stem, candidate (a) is preferred as it incurs the fewest identity violations.

5.2.2 Mid vowel lowering.

Kikuria also exhibits a process by which the upper mid vowels /e o/ are lowered to [ɛ ɔ] when preceded by these vowels. This process, Mid Vowel Lowering, is illustrated by the examples in (5.10).

(5.10) Mid vowel lowering.

oko-rɔ́g-ɛ́r-a	'to bewitch for'
okotɛ́rɛ́k-ɛr-á	'to brew for'
okogɔ́ɔ́g-ɛ́r-á	'to slaughter for'
ogo-sɔ́k-ɛ́r-ǎ	'to poke for'

Mid vowel lowering is motivated by an alignment constraint (5.11) requiring that a height node be aligned with the right edge of the word. The low vowel does not trigger harmony.

(5.11) Align(Height Stem$_I$, R, Word, R)

AlignHtR = for all vowels affiliated with the stem input that are specified for [closed], there exists a Height node in the output such that the Right edge of Height and the Right edge of the word coincide.

Satisfaction of AlignHtR also incurs a violation of Ident[cl].

Tableau 5.5

-rɔg-er → rɔg-ɛr-	AlignHtR	Ident[cl]
a. ☞ ɔ ɛ / Ht <Ht>		*
ɔ e / Ht Ht	*!	

The vowel [a] does not undergo harmony as HeightPl, Ident[dor], and Ident[cor] are ranked above AlignHtR.

Tableau 5.6

-rɔg-er-a→-rɔg-ɛr-a	HeightPl	Ident[dor]/[cor]	AlignHtR	Ident[cl]
a. ☞ ɔ ɛ a / Ht <Ht> Ht			*	*
b. ɔ ɛ ə / Ht <Ht> <Ht>	*!			**
c. ɔ ɛ ɔ / Ht <Ht> <Ht>		*!		**

Harmony does not apply leftward. This is a result of Ident[cl], which, while ranked below AlignHtR, prefers candidates that satisfy alignment at the lowest cost. Candidate (b) in Tableau 5.7 violates Ident[cl] when Height is shared among all stem vowels.

Tableau 5.7

okorɔger- → okorɔger-	AlignHtR	Ident[cl]
a. ☞ o o ɔ ɛ / H H H <H>		*
b. ɔ ɔ ɔ ɛ / <H> <H> H <H>		**!*

5.2.3 Coalescence

Kikuria also exhibits coalescence. The vowel [o] combines with [a] to form [ɔɔ] as shown in the examples in (5.12). Examples such as *omɔɔ́rɔ* 'river' (← /omo-ɔrɔ/) indicate that a similar pattern is found from combinations involving [ɔ] and [a], though these fall outside the definition of coalescence in). Further research is needed to determine whether comparable examples are available involving [e] and [a].

(5.12) Coalescence.

/oko-atya/	→ ogɔɔ́tya	'to be split'	cf. atyá	'split!'
/oko-aha/	→ okɔɔ́ha	'to pick vegitables'	cf. ahǎ	'pick vegetables!'
/oko-aga/	→ okɔɔ́ga	'to weed'	cf. agǎ	'weed!'
/omo-ana/	→ omɔɔ́na	'child'	cf. abaána	'children'
/obo-ana/	→ obɔɔna	'childhood'		

Coalescence is analyzed here, as in §4.1.2, as the interaction of constraints. ONS and MAX are ranked high so that Uform is violated to resolbe hiatus without deletion. The ranking ONS, MAX » UFORM, *[closed] achieves the correct results.

Tableau 5.8

o a → ɔɔ	ONS	MAX	UFORM	*[closed]
a. ☞ ɔɔ			*	*
b. əə			*	**!
c. a		*!		
d. oa	*!			*

The optimal form is (a) in Tableau 5.8 since this candidate satisfies ONS by merging the Height node of [a] and the V-Place of [o]. An instance of [closed] is inserted to satisfy PL→[cl]. Parsing the height node of [o] and the V-Place of [a] creates a mid central vowel, and violates *[closed] twice. Candidate (c) resolves hiatus through deletion, incurring a fatal MAX violation. Candidate (d) fails to resolve hiatus and fatally violates ONS.

Tableau 5.9

o a → ɔɔ	PL→[cl]	*[closed]
a. ☞ ɔɔ VPL <HT><VPL> HT [cl]		*
b. DD VPL <HT><VPL> HT	*!	
c. əə <VPL> HT VPL <HT>		**!

Coalescence in Kikuria follows the pattern described in the previous chapter. The height of the lower input vowel is preserved while the place of the remaining input vowel is

preserved. As there is no low rounded vowels in Kikuria, combinations involving /o a/ result in the epenthesis of an occurrence of [closed] to the Height node of [a] so that the surface vowel is [ɔ].

5.3 Interaction

The processes of partial height harmony, high vowel lowering, and mid vowel lowering interact in Kikuria. This section examines that interaction.

(5.13) Vocalic alternations in Kikuria—summary.

a. partial height harmony	/ɛ ɔ e o/	→ [e o i u]	before [i u]
b. mid vowel lowering	/e o/	→ [ɛ ɔ]	after [ɛ ɔ]
c. high vowel lowering	/i u/	→ [e o]	before [e o]
d. coalescence	/o-a/	→ [ɔ]	

The effects of partial vowel harmony are always observed, even in cases in which one of the complete height harmonies might apply. In an example such as /oko-siik-er-i-a/, the vowel of the applied suffix could trigger the lowering of the high vowel of the root, or the high vowel of the causative suffix could trigger one-step raising of the vowel of the applied. As this word is pronounced ***uku-siik-ir-ya*** 'to cause to close for,' it is clear that partial height harmony did apply (Chacha and Odden 1995:22–23). (The infinitive prefix is raised by the high vowel of the root.)

(5.14) oko-siik-er-i-a → *uku-siik-ir-y-a.*

oko	siik	er	i	a
INF	'close'	applied	causative	FV

Other examples showing this effect are provided below.

(5.15) Partial height harmony.

ugu-siik-ir-y-a	'to make close for'
uku-rug-ir-y-a	'to make cook for'
ugu-siind-ir-y-a	'to make win for'

This reflects a ranking in which ALIGN[cl] is highly ranked. It is not clear, in candidate (a), whether ALIGNHTL is violated. The root and suffix vowels have the same height in *ugu-siik-ir-y-a* 'to make close for,' but that may or may not reflect a complete height assimilation. In the absence of phonological or phonetic suggestion of one sturcture over another, ALIGNHT is assumed to be satisfied in candidate (a), though nothing crucial depends on this particular analysis.

Tableau 5.10

-siik-er-i→-siik-ir-i-	Align[cl]	AlignHtL
a. ☞ siik ir i [cl]		?
b. seek er i Ht	*!	

In examples in which both partial height harmony and mid vowel lowering may apply, Chacha and Odden (1995) report variation in which only partial height harmony applies, or both processes apply.

(5.16) Partial Height Harmony and Mid Vowel Lowering.

underlying		*both apply*		*partial h. h.*	*gloss*
/oko-rɔg-er-i-a/	→	oko-rog-er-y-a	~	oko-rog-ir-y-a	'bewitch'
/oko-gɔɔg-er-i-a/	→	oko-goog-er-y-a	~	oko-goo-ir-y-a	'slaughter'
/oko-tɛrɛk-er-i-a/	→	ogo-terek-er-y-a	~	ogo-terek-ir-ya	'brew'

In examples such as, *oko-rog-er-y-a*, both mid vowel lowering and partial height harmony must apply. The lower-mid vowel of the root lowers the applied suffix to [ɛ], and partial height harmony raises both one step to [e]. To achieve this outcome, the constraints Align[cl] and AlignHtR must be ranked equally, so that the best candidate violates neither.

Tableau 5.11

rɔg-er-i→rog-er-y	Align[cl]	AlignHtR
a. ☞ o e y Ht [cl]		
b. ɔ ɛ y Ht [cl]	*!	
c. o i y Ht Ht Ht [cl]		*!

In cases where only partial height harmony applies, the causative suffix raises the applied suffix one step, and the root vowel one step. This form suggests the ranking of Align[cl] » AlignHtR.

Tableau 5.12

rɔg-er-i→rog-ir-y	Align[cl]	AlignHtR
a. ☞ o i y [cl]		*
b. ɔ ɛ y Ht	*!	

However, the ranking in Tableau 5.12 is still best satisfied by a third candidate in which neither constraint is violated (similar to (a) of Tableau 5.11). Therefore, for the candidate in which only partial height harmony applies, there must be some identity constraint that outranks AlignHtR so that the ranking Align[cl] » C » AlignHtR is observed.

Tableau 5.13

rɔg-er-i→rog-ir-y	Align[cl]	C	AlignHtR
a. ☞ o i y [cl]			*
b. ɔ ɛ y Ht [cl]	*!		
c. o e y Ht [cl]		*!	

The variation in (5.16) is thus described in terms of two rankings, one in which AlignHtR outranks C, and the other in which C outranks AlignHtR.

The interaction of the two complete height harmonies represents a conspiracy. Observe the behavior of the applied suffix *-er* in (5.17). This suffix triggers the complete lowering of [ii] in *ugusiikira* but undergoes complete lowering to [ɛ] in *okorɔgɛra*.

(5.17) The applied suffix.

/oko-siik-er-a/	→	ugu-siik-i̱r-a	'to close for'
/oko-rɔg-er-a/	→	oko-rɔg-ɛ̱r-a	'to bewitch for'

Either ranking, (AlignHtL » AlignHtR or AlignHtR » AlignHtL) selects an incorrect form (marked by ☛).

Tableau 5.14

	ALIGNHTL	ALIGNHTR	ALIGNHTR	ALIGNHTL
a. rɔg-ɛr-a	*		☞	*
b. rog-er-a	☛	*	*	
a. siik-ir-a	*		☛	*
b. seek-er-a	☞	*	*	

The surface forms, however, always apply the harmony that produces the lower surface vowel. That is *er* undergoes harmony after [ɛ ɔ] but triggers harmony after [i u]. Both harmonies have a lowering effect. This is taken as evidence for the high ranking of the constraint *[closed]. The two alignment constraints and *[closed] are unranked relative to each other, but select the correct candidate for both forms as shown in Tableau 5.15.

Tableau 5.15

	*[closed]	ALIGNHTL	ALIGNHTR
a. ☞ rɔgera	**	*	
b. rogera	***!*		*
a. siikira	*****!*	*	
b. ☞ seekera	****		*

ALIGN[cl] is ranked above *[closed].

Tableau 5.16

omorɔgi → omorogi	ALIGN[cl]	*[closed]
a. ☞ rog-i		*****
b. rɔg-i	*!	****

Vowel coalescence interacts with Mid Vowel Lowering as demonstrated by the examles in (5.18). In an form such as *andeka* 'write!,' Mid Vowel lowering cannot take place since the low vowel [a] may not trigger the process. In the infinitive, where coalescence has taken place, Mid Vowel Lowering also applies.

(5.18) Coalescence feeds Mid Vowel Lowering.

/oko-andek-a/ → okɔɔndɛk-a 'to write'
/oko-ag-er-a/ → okɔɔgera 'to weed for'

Mutually unranked ONS and ALIGNHTR derive the correct forms.

Tableau 5.17

oko-andek-a → okɔɔndɛka	ONS	ALIGNHTR
a. ☞ ok ɔɔ ndɛk a HT <HT> HT		
b. ok ɔɔ ndek a HT HT HT		*!
c. oko a ndek a HT HT HT	*!	

The examples in (5.19) show that Partial Height Harmony applies in cases in which coalescence and Mid Vowel Lowering also apply.

(5.19) Coalescence, Mid Vowel Lowering, and Partial Height Harmony.

/oko-andek-i-a/ → okoóndékyá 'to cause to write for'
/oko-ag-er-i-a/ → okoógéryá 'to cause to weed for'
/oko-at-er-i-a/ → okoótéryá 'to cause to split for'

The examples in (5.19) demonstrate that if ALIGN[cl] is ranked above ONS and ALIGNHTR, these constraints achieve the correct results. Recall from Tableau 5.12 that ALIGN[cl] is ranked above ALIGNHTR.

Tableau 5.18

oko-andek-i-a → okoondekya	ALIGN[cl]	ONS	ALIGNHTR
a. ☞ ok oo ndek y a HT <HT> HT [cl]	*		
b. ok oo ndik y a HT HT HT [cl]	*		*!
c. oko a ndik y a HT HT HT [cl]	**!	*	
d. ok ɔɔ ndik y a HT HT HT [cl]	**!		*

oko-andek-i-a → okoondekya	ALIGN[cl]	ONS	ALIGNHTR
e. ok ɔɔ ndɛk y a HT <HT> HT [cl]	**!		

5.4 Summary

Height alternations in Kikuria are described in terms of Optimality Theory and the Incremental Constriction Model. Employing the incremental feature [closed] allows partial height harmony to be characterized in a straightforward way. Partial height harmony interacts with two processes of complete height harmony and vowel coalescence in Kikuria. All of these phenomena, and their interaction, are handled by the Incremental Constriction Model within the framework of Optimality Theory. Analyzing a number of phenomena that interact in a single language demonstrates that Optimality Theory is able to handle larger parts of a language's grammar than was demonstrated in previous chapters.

CHAPTER 6

6.0 Conclusion

This work has presented new approach to the description of vowel height, one that reflects the phonetic and phonological properties of vowel height. This proposal, the Incremental Constriction Model, characterizes vowel height as a single phonetic scale. Vowel height distinctions are described as steps along the vowel height dimension, represented in terms of multiple occurrences of the monovalent feature [closed]. As a vowel's height increases, so does the number of instances of [closed] that characterize that vowel.

There is abundant evidence that vowel height should be treated as a single phonetic and phonological dimension, some of which was presented here. The most powerful support for this view of vowel height is a survey of languages that exhibit partial height harmony that was presented in Chapter 3. This exhaustive survey includes all known cases of vowel harmony in which a vowel moves toward the height of another vowel, but does not achieve that height. All fifteen cases of partial height harmony involve raising, and all involve one-step changes. This generalization, that all partial height harmonies are one-step raisings, has not previously been mentioned. This generalization is not restricted to assimilations, either, since three cases of morphologically induced height alternations also involve one-step raising.

As robust as this generalization is, no previous approach to vowel height is able to capture the fact that partial height harmony always raises its target one step. All previous models of vowel height employ at least one feature that corresponds to lowered height, e.g., [–high], [+open], or the particle *a*. These approaches are at a loss to explain why no language spreads one of these elements to the exclusion of all others. All cases of partial height harmony are described in the Incremental Constriction Model as an assimilation of the feature [closed].

Among the languages exhibiting partial height harmony is a subclass of languages that raise more than one vowel simultaneously. In Nzɛbi, for example, the vowel [a] raises to [ɛ], the vowels [ɛ ɔ] raise to [e o], and [e o] raise to [i u] in assimilation to [i]. Each of these changes is characterized in the Incremental Constriction Model as an increase of one instance of [closed]. To describe this change in a multiple feature analysis requires the grammar to make reference to a different feature for each vowel, i.e., [low] for [a], [ATR] for [ɛ ɔ], and [high] for [e o]. Languages such as Nzɛbi receive a straightforward treatment using [closed]. Multiple feature analyses must explain why Nzɛbi simultaneously raises some vowels but advances (the tongue root of) others.

Diphthongization is another process that illustrates the scalar nature of vowel height. Languages that exhibit diphthongization often raise or lower one half of a monophthong. These one step changes receive an elegant account if described in terms of [closed], as shown in Chapter 4. The stepwise shifts seen in diphthongization defy a unified analysis using disparate features to characterize vowel height.

The Incremental Constriction Model was also shown to provide an account of the processes of complete height harmony and vowel coalescence. Describing height in terms of the feature [closed], then, allows for an account for the full range of vowel height phenomena while correctly ruling out unattested assimilations. In Chapter 5, an analysis of height alternations in Kikuria was presented using the Incremental Constriction Model and the framework of Optimality Theory. Kikuria exhibits partial height harmony, complete height harmony, and coalescence, all of which interact in the phonology. These phenomena and their interaction were accounted for using constraints motivated in the previous chapters.

Previous approaches to vowel height have incorrectly predicted partial lowerings to exist while this phenomenon is unattested in the world's languages. Some models have described height in terms of multiple, unrelated features missing the generalization that languages do treat vowel height contrasts as steps along a single scale. The Incremental Constriction Model characterizes vowel height in a way that is consistent with the phonetic and phonological properties of vowel height cross-linguistically.

APPENDIX A

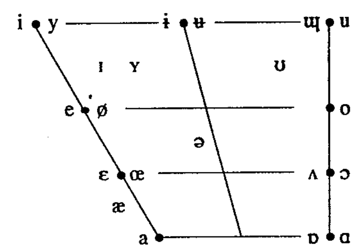


Table A.1 Vowels of the International Phonetic Alphabet.

	front unround		front round		central round		back round	
	Bruce	here	Bruce	here	Bruce	here	Bruce	here
high	i	i	y	ü	ʉ	ʉ	u	u
uper-mid	e	e	ø	ö			o	o
lower-mid	ɛ	ɛ	œ	œ			ɑ	ɑ
low	æ	æ						

Table A.2 Vowels of Scanian Sweedish.

here	G phon.	G ortho.	D&M phon.	D&M ortho.	CL phon.	CL ortho.	M	H	CM
j	i	e̿	i	i	i	i	i	i	j
ɥ	u	o̿	u	u	u	u	u	u	ɥ
i	ɨ	ē		ē	ɩ	e	ẹ		ị
u	ʉ	ō		ō	ω	o	ọ		ụ
ɪ	e	e̿	ɨ	ē	ɪ	e	e	ɪ	i
ʊ	o	o̿	ʉ	o̿	ʊ	o	o	ʊ	u
e	ẹ	è	e	e	e	ê	ɛ̣	e	ẹ
o	ọ	ò	o	o	o	ô	ɔ̣	o	ọ
ɛ	ɛ	è	ɛ	è	ɛ	ê	ɛ	ɛ	e
ɔ	ɔ	ò	ɔ	ò	ɔ	ô	ɔ	ɔ	o
a	a	a	a	a	a	a	a	a	a

Table A.3 Vowel correspondences for the Sotho languages. G = (Guma 1971), D&M = (Doke and Mofokeng 1952), CL = (Cole 1955) =, M = (Monareng 1962), H = (Harris 1987), CM = (Clements 1991).

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APPENDIX A

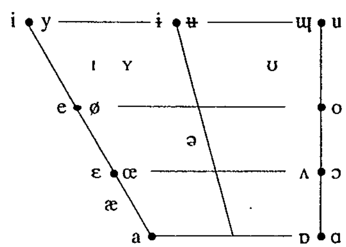

Table A.4 Vowels of the International Phonetic Alphabet.

	front unround		front round		central round		back round	
	Bruce	here	Bruce	here	Bruce	here	Bruce	here
high	i	i	y	ü	ʉ	ʉ	u	u
uper-mid	e	e	ø	ö			o	o
lower-mid	ɛ	ɛ	œ	œ			ɑ	ɑ
low	æ	æ						

Table A.5 Vowels of Scanian Sweedish.

here	G		D&M		CL		M	H	CM
	phon.	ortho.	phon.	ortho.	phon.	ortho.			
į	i	ē̄	i	i	i	i	i	i	į
ų	u	ō̄	u	u	u	u	u	u	ų
i	ɨ	ē		ē	ɩ	e	ẹ		ị
u	ᵾ	ō		ō	ω	o	ọ		ụ
ɪ	e	ē̄	ɨ	ē̄	ɪ	e	e	ɪ	i
ʊ	o	ō̄	ʉ	ō̄	ʊ	o	o	ʊ	u
e	ẹ	è	e	e	e	ê	ɛ̣	e	ẹ
o	ọ	ò	o	o	o	ô	ɔ̣	o	ọ
ɛ	ɛ	è	ɛ	è	ɛ	ê	ɛ	ɛ	e
ɔ	ɔ	ò	ɔ	ò	ɔ	ô	ɔ	ɔ	o
a	a	a	a	a	a	a	a	a	a

Table A.6 Vowel correspondences for the Sotho languages. G = (Guma 1971), D&M = (Doke and Mofokeng 1952), CL = (Cole 1955) =, M = (Monareng 1962), H = (Harris 1987), CM = (Clements 1991).

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