Vowel Height Assimilation in Bantu Languages
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1. Introduction

The linguistic study of a population of closely related languages offers interesting possibilities for observing minimal patterns of variation across the same or very similar structural conditions. From this point of view, the Bantu languages offer especially rich materials for the study of vowel height and other phonological processes. While their vowel systems are quite similar at the level of underlying representation, at the surface they show subtle differences in respect to how vowels of different heights may be sequenced within the stem or word. The study of these differences can shed light on the formal representation of vowel height in phonological feature theory.

Many Bantu languages preserve the 7-vowel system of Proto-Bantu in which vowels are arrayed in four heights, as shown in (1a). Others have reduced this to a 3-height system, usually through the merger of the two highest ranks, as shown in (1b).

(1) Bantu vowel systems:

	a. 7-vowel (Proto-Bantu, Kikuyu, etc.)			b. 5-vowel (Runyakore, Luganda, etc.)		
height 4:	i̮		u̮			
height 3:	i		u	i		u
height 2:	e		o	e		o
height 1:		a			a	

In most Bantu vowel systems, phonological rules of height assimilation typically create striking patterns of alternation. One very common pattern, described by Greenberg (1951) and attributed to Proto-Bantu by Meeussen (1967), is illustrated below. In this pattern, the first vowel of a stem determines the height of subsequent vowels: [i] is lowered to [e] after [e] and [o], and [u] is lowered to [o] after [o]. For example, in the 7-vowel system of Kikuyu, the applied suffix, which elsewhere has the form [-ir], appears as [-er] after either of the height 2 vowels, as shown in the second column in (2). (Tones are omitted in these and all following examples, since they are irrelevant to the rules under discussion.)

(2) vowel height alternations in Kikuyu:

tị̣ɣ-ir-a	'stop for'	ker-er-a	'chop for'
rụt-ir-a	'work for'	ror-er-a	'look at'
rih-ir-a	'pay for s.o. else'		
kum-ir-a	'rebuke for'		
ɣamb-ir-a	'bark at'		

The same alternations are found in languages like Runyakore which have reduced the original seven vowels to five. The comparable alternations are shown in (3):

(3) vowel height alternations in Runyakore:

hik-ir-a	'reach for, arrive'	reet-er-a	'bring for'
kub-ir-a	'fold for'	kor-er-a	'work for'
gamb-ir-a	'say to'		

Using the classificatory scheme in (1), we can generalize over these cases as follows: height 3 vowels are lowered to height 2 after height 2 vowels, except that a back vowel is lowered only after a back vowel.[1]

Most recent treatments of vowel height in Bantu have described vowels in terms of the binary features [high] and [low]. In other respects, however, analyses have differed. For example, in systems with four vowel heights, the height 3 vowels have sometimes been treated as [+high] and sometimes as [-high]. This disagreement is reflected in the widespread use of two different transcription systems for Bantu vowels. One transcribes the highest four vowels as /ị ụ i u/ as shown in (1), implying that the height 3 vowels are high. The other transcribes them as /i u e o/, implying that they are mid. Furthermore, while the height 2 vowels have been most often treated as [-low], some analysts have characterized them as [+low] (see section 5). A further problem arises from the fact that the features [high] and [low] only characterize three heights, due to the fact that [+high] cannot combine with [+low]. An additional feature is required to characterize the fourth height of languages like Kikuyu. Many linguists have used [ATR] for this purpose, but others have used [tense]. As a result of these (and other) disagreements, there does not yet exist a uniform model for the representation of vowel height in Bantu.

The aim of this paper will be to seek an improved model of vowel height for Bantu languages. Based on a study of several representative patterns of height assimilation, it will suggest that vowel height can be regarded as a uniform phonetic and phonological parameter, characterized in terms of a single, binary feature [open]. This approach differs both from the standard feature system discussed above, in which vowel height is described in terms of several formally unrelated features such as [high] and [low], and from alternative models in which vowel height is characterized in terms of one-valued features, also called particles (see, for example, Schane 1984). The new approach is described in the next section.[2] The following sections apply it to several different Bantu vowel height systems, and show that it provides a straightforward account of several different types of assimilation processes, while allowing a uniform characterization of vowel height across superfically different systems.

2. A Hierarchical Model of Vowel Height

In the model proposed here, vowel height forms a uniform phonological dimension, which we may designate by the feature [open]. This dimension can be viewed as defining an abstract phonological "space" which is divided into a series of regions, or *registers*. The first level of division partitions the space into two *primary* registers. Either (or both) of these primary registers can then be divided into two *secondary* registers. Either (or both) of the secondary registers can then be subdivided in turn, and so on. This conception is informally schematized in Figure 1:

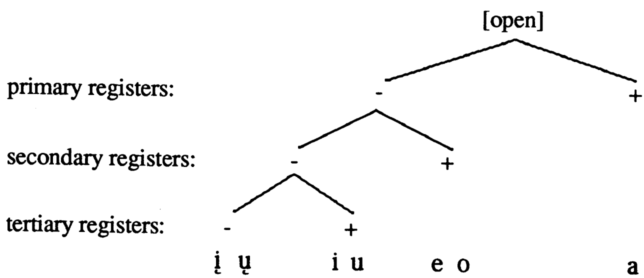


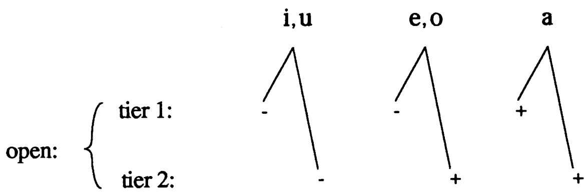
Figure 1: A hierarchical conception of vowel height.

At the top of this diagram we see a split of the vowel height space into two primary registers, designated by the features [-open] and [+open]. Vowels can be assigned to either of these primary registers. If no further distinctions are made, we have a 2-height vowel system such as Classical Arabic /i u a/, in which the [-open] vowels are /i u/ and the [+open] vowel /a/. If one of the two primary registers is futher divided to form two secondary registers, we have a 3-height system. In Classical Latin, for example, the higher primary register, designated by [-open], is subdivided into two secondary registers, creating the 3-height system /i u e o a/. And registers can be further subdivided to create successive new subregisters, yielding 4-height systems (such as that of Italian or Yoruba) and eventually 5-height systems (such as that of the Sotho languages, discussed below).

In principle, since vowel height constitutes a uniform phonetic dimension, there is no upper limit on the number of subregisters that may be created. In reality, however, 5-height systems seem to constitute a *de facto* upper limit, due most likely to inherent limits on the ability of the auditory system to resolve differences between sounds that approach a perceptual threshold.

I will call this conception a *hierarchical* model of vowel height. In order to formalize this model in terms of current multi-tiered feature theory, we may array the binary feature [±open] on several autosegmental tiers, assigning each a rank from 1 to *n*. The feature [±open] arrayed on a tier with any rank *i* assigns a vowel to one of the two registers characterized at rank *i* of the hierarchy. Thus, the feature [+open] on tier 1 assigns a vowel to the lower of the two primary registers, while [-open] on this tier assigns it to the higher primary register. The same features on tier 2 assign vowels to the lower or higher of the secondary registers, and so forth. This model is illustrated in (4), which represents the vowels of Latin:

(4)



In this diagram, the nonlow vowels /i u e o/ are assigned to the higher of the two primary registers, designated by [-open] on tier 1. Within this primary register, the high vowels /i u/ are assigned to the higher of the two secondary registers, and /e o/ are assigned to the lower one. /a/ is assigned to the lower of the two primary registers, and (redundantly) to its lower (and only) secondary register, indicating that it is the lowest possible vowel in the system, phonologically speaking.

For convenience, we will hereafter designate any occurrence of the feature [±open] on tier *i* as $[\pm open_i]$. Thus, for example, $[+open_2]$ designates an occurrence of [+open] on tier 2.

Natural classes are defined by identical feature specifications along any tier. Thus in (4), /i u e o/ constitute a natural class since they are characterized by the feature [-open] on tier 1, and similarly, /e o a/ constitute a natural class since they are characterized by [-open] on tier 2, even though they belong to different primary registers.

The logic of this system requires that a vowel can only be characterized for a lower register if it is also characterized for the higher register of which the lower register is a subdivision. We may formalize this requirement in terms of a universal implication $[open_i] \rightarrow [open_{i-1}]$, which states that the presence of a lower-ranked feature in a vowel implies the presence of a feature of the next higher-ranked category. Thus if $[\alpha open_i]$ characterizes a vowel, for some value of α, $[\beta open_{i-1}]$ must be present as well, for some (not necessarily identical) value of β. To put it another way, the presence of a feature of any lower register in a vowel "activates" all the higher registers. (This means, for example, that a vowel cannot be characterized for [+open$_2$] unless it is also characterized for some value of [open$_1$].)

In this model, the prototypical Bantu 7- and 5-vowel systems given in (1) can be characterized as shown in (5). (Association lines are omitted here for convenience.)

(5) the feature representation of vowel height systems:

		į ų	i u	e o	a
a. 4-height systems :		į ų	i u	e o	a
(primary registers)	open$_1$:	-	-	-	+
(secondary registers)	open$_2$:	-	-	+	+
(tertiary registers)	open$_3$:	-	+	+	+
b. 3-height systems:			i u	e o	a
(primary registers)	open$_1$:		-	-	+
(secondary registers)	open$_2$:		-	+	+

Vowels are given here in fully-specified form with all redundant values filled in, showing how they would appear in surface representations if no feature-changing rules applied to them. In agreement with most current work (e.g. Clements 1987, Archangeli 1988), however, I assume that vowels are underspecified in underlying representations, and receive their surface values through the operation of redundancy rules. Thus, for example, [+open$_2$] and [+open$_3$] are redundant in [+open$_1$] (low) vowels, since [+open$_1$] entails both [+open$_2$] and [+open$_3$]. Accordingly, these features will not appear in underlying feature representations, and will be introduced in the course of derivations through the operation of redundancy and default rules. I will discuss underspecification below whenever it is relevant to the discussion.

As (5) shows, 3-height systems are analyzed in the same way as the Latin vowels shown in (4). In feature terms, 3-height systems form a strict subset of 4-height systems, and are derived from them by eliminating [open$_3$] from vowel representations.

Since [open] is a binary feature, any vowel can be characterized as either [+open] or [-open] on each tier. In a multitiered model of the sort proposed in Clements (1985, in press) and Sagey (1986), this means that each vowel is potentially able to trigger rules of assimilatory lowering (by spreading the feature [+open]) and assimilatory raising (by spreading [-open]). In contrast, if [open] were treated as a one-valued feature [+open], as in theories of particle phonology (Schane 1984), we would predict that only lowering assimilation could take place. Both types of assimilation occur in Bantu languages, as we will see below.

By imposing a hierarchy on the registers, we express the view that some are more fundamental to a system than others. The more basic registers, such as the primary registers which distinguish the low vowels from all others, are typically those that involve the most salient distinctions and that prove the most resistant to historical merger and synchronic neutralization. In contrast, the less basic registers, such as the tertiary registers which differentiate the height 4 and height 3 vowels, are often less well separated in perceptual terms, and are frequently neutralized by historical mergers and by synchronic rules and constraints.

If we adopt the model in (5), these patterns of merger and neutralization can be expressed as the loss of a lower-ranked feature category, such as [open_3], from the set of distinctive features. For example, as noted earlier in connection with (1), 4-height systems typically simplify to 3-height systems through the merger of vowel heights 3 and 4 (that is, i̞ u̞ i u > i u). The model in (5) allows us to express this merger in terms of the loss of [open_3], designating the tertiary registers.

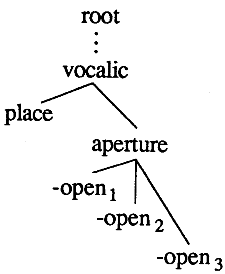
We also find synchronic mergers in certain contexts. For example, the noun class prefixes are reconstructed with only the four vowels /i̞ i u a/ in Proto-Bantu (Meeussen 1967), and /i̞/ is eliminated from these prefixes in many modern Bantu languages, leaving only three vowels /i u a/. This system is also found in some suffix classes.[3] We can represent such reduced systems by eliminating both of the lower-ranked registers, leaving only the primary registers, as shown in (6) (/I U/ are written in upper case to indicate their archiphonemic status in these systems):

(6) reduced 3-vowel system:		I	U	a
(primary registers)	open_1:	-		+

(Here as in (5) both values of [open_1] are given, although strictly speaking [-open_1] is redundant, being predictable from the other features of /I/ and /U/.)

Let us consider now how the feature [open] can be integrated into a multi-tiered model of feature representation of the sort proposed in Clements (1985), Sagey (1986) and much subsequent work. I suggest that each occurrence of the feature [open] links directly to an *aperture* node, which links in turn to the *vocalic* node. This conception is illustrated in (7), which represents the vowel [i̞] in the 4-height system shown in (5).

(7)

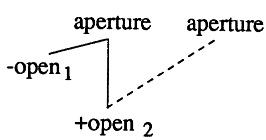


Other vowel features (not shown here) link to the place node, although the internal structure of this node is not crucial to the present discussion. Given the model in (7), we predict that any node can spread. Thus, for example, we expect that any occurrence of [open] can spread, as well as the aperture (and place) nodes themselves. These predictions are well supported by Bantu data, as discussed below.[4]

In an alternative view, one might suggest that the various tokens of [open] are linked not as sisters (as in (7)) but one under another, forming a chain. This view would be attractive, since it would express the hierarchical ranking of each feature [open_i] directly: the higher the feature, the higher its rank. However, such a model would predict that the spread of any feature [open] entails the concomitant spread of all features linked under it. This prediction appears to be wrong. The evidence provided by scalar rules, to be discussed in more detail in section 3, shows that the spread of a higher-level feature, such as [open_1], crucially does *not* entail the spreading of lower-ranked features, such as [open_2] and [open_3]. In contrast, all evidence discussed in this paper is consistent with the predictions of the model in (7), and accordingly we will continue to assume this model in the rest of the discussion.

In this model, then, the height assimilation rules illustrated in (2) and (3) can be given a unified statement as follows:

(8) Bantu Vowel Lowering (7- and 5-vowel systems):



conditions:
(i) stem domain
(ii) structure-preserving

This rule applies to the feature characterizations in (5), spreading the feature [$+\text{open}_2$] from a height 2 vowel to a following vowel in the same stem. In both 7- and 5-vowel systems, it will lower the height 3 vowels [i u] to height 2 [e o]. Vowels of lower heights are of course not changed, since they are [+open2] already.

Condition (i) restricts the rule to the stem domain. Condition (ii) requires it to apply in a structure-preserving fashion, that is, in such a way that it does not create feature combinations not already present at the level at which the rule applies. (This condition is intended as a shorthand way of saying that the rule to which it is attached belongs to a stratum at which the marking conditions governing underlying feature combinations are still in force; see Kiparsky (1985) for fuller discussion.) Without this condition, the rule would apply too generally, lowering height 4 vowels as well as height 3 vowels. With this condition, however, the rule cannot apply to height 4 vowels since the feature combination that would result, namely [+open2, -open3], does not occur at this level.

We have tacitly assumed up to this point, crucially to the analysis, that the low vowels of Bantu constitute a separate height, distinct from that of the mid vowels [e o]. This decision stems in part from the fact that low vowels typically do not trigger height assimilation rules such as rule (8). This behavior is directly expressed in our analysis by assigning low vowels a separate height ([+open1]), and explicitly excluding them from the domain of height assimilation rules.[5] We will see independent evidence for the treatment of low vowels as a separate height in our discussion of scalar rules in section 4.

In sum, given the analysis of Bantu vowels proposed in (5) above, rule (8) accounts for the patterns of vowel alternation found in both 7- and 5-vowel systems.

3. Total Height Assimilation in Kimatuumbi

Now that we have examined the most general pattern of vowel height assimilation in Bantu languages, let us consider several more idiosyncratic patterns.

One interesting example, illustrating *total* height assimilation (assimilation of all vowel height features), comes from Kimatuumbi, a Bantu language of Tanzania described by Odden (1989, 1990). In this language, stem-initial vowels are drawn from the full set of seven given earlier in (5a), while medial vowels are drawn from the reduced set of three given in (6). These feature characterizations are repeated below for convenience:

(9) Kimatuumbi vowels

	a. stem-initial:				b. stem-medial:	
	i̯ u̯	i u	e o	a	I U	a
open1:	-	-	-	+	-	+
open2:	-	-	+	+		
open3:	-	+	+	+		

The height assimilation rule causes a nonlow suffix vowel to acquire the height of a preceding nonlow vowel (not just of a height 2 vowel, as in the more widespread Bantu rule (8) discussed earlier). It applies only within the domain of the stem. As in the case of rule (8), which may be its ancestor, this rule does not cause /U/ to assimilate to /e/. In contexts where this rule does not apply, such as following a low vowel, noninitial /I/ and /U/ are realized as [į] and [ų]. Thus we find the following realizations (tones are omitted):

(10) Kimatuumbi height assimilation:

underlying:	*surface:*	*example (stem):*	
į + I	į + į	yįpįlya	'thatch with for'
į + U	į + ų	lįbųlwa	'be ground'
ų + I	ų + į	ųtįka	'be pullable'
ų + U	ų + ų	yųpųlwa	'be served'
i + I	i + i	twikilwa	'be lifted' (of a load)
i + U	i + u	tikulya	'break with'
u + I	u + i	ugilwa	'be bathed'
u + U	u + u	kumbulya	'beat with'
e + I	e + e	cheengeya	'make build'
e + U	e + ų	kwemųlya	'comb'
o + I	o + e	boolelwa	'be de-barked'
o + U	o + o	bomolwa	'be destroyed'
a + I	a + į	asįmįlwa	'be borrowed'
a + U	a + ų	tyamųlya	'sneeze on'

In order to account for the total height assimilation, both [open2] and [open3] must spread. We do not want to spread [open3] by a separate rule, since as Odden points out, the proposed new rule would have to apply under exactly the same conditions (and have the same set of exceptions) as the rule spreading [open2]. Nor can we modify rule (8) by stipulating that *both* of these features must spread, since [open2] and [open3] do not by themselves form a single constituent in phonological representations (cf. (7)); in the framework assumed here, assimilation rules apply only to single constituents (Clements 1985).

An alternative is available, however, if following Odden's original analysis, we allow the entire aperture node (or height node, in Odden's terminology) to spread, holding all other conditions constant. The revised rule is stated in (11).[6]

(11) Kimatuumbi Height Assimilation:

vocalic

aperture aperture

| |

-open_1 -open_1

conditions:
(i) stem domain
(ii) left-to-right

This rule spreads an aperture node characterized by the feature [-open$_1$] to a vocalic node characterized by the same feature. The second aperture node then delinks as a result of a general convention disallowing branching configurations (Clements 1990). Since it is the aperture node itself that spreads, rather than any single feature, height assimilation is total.

Let us compare this feature analysis with an analysis using the traditional features [high] and [low]. Since these two features can only characterize a maximum of three vowel heights, they are not adequate by themselves to characterize a 4-height system such as that of Kimatuumbi. In order to express four vowel heights, standard frameworks must introduce an additional feature such as [ATR], as shown below:

(12)

	į ų	i u	e o	a
low	-	-	-	+
high	+	+	-	-
ATR	+	-	-	-

It will easily be seen that both analyses predict exactly the same set of natural classes. Thus, comparing this chart to the one in (9), we see that [αlow] corresponds to [αopen$_1$], [αhigh] to [-αopen$_2$], and [αATR] to [-αopen$_3$]. How, then, can these two analyses be distinguished?

To answer this question, let us consider the formal nature of assimilation more closely. Current phonological theory requires assimilation rules to be expressed in terms of node *spreading*, rather than the changing of feature specifications as in earlier theories. This assumption has been built into the rule formulations given above. A further constraining assumption is that only *single* nodes may spread; this assumption has also been incorporated into the analyses given earlier.

It follows directly from these assumptions that the height assimilation rule of Kimatuumbi must be expressed as the spreading of a single node. In a system employing features like those of (12), what can this node be? It cannot be the dorsal node, in the sense of Sagey (1986), since this node is defined in terms of the activity of the tongue body, and [ATR] is a tongue root feature. Even if we were to extend the definition of dorsal in such a way as to include the tongue root and link [ATR] under the dorsal node, we would still be unable to express Kimatuumbi spreading, since the dorsal node also dominates the tongue body feature [back], which does not spread in this rule.

We must therefore assume a somewhat different organization from that proposed by Sagey, in which a single node, such as the aperture or height node, dominates [high], [ATR] and perhaps [low]. But this assumption leads to a new problem. As is well known, [ATR] defines the location of a vocal tract constriction defined in terms of the activity of a specific articulator, the tongue root (Painter 1967, Lindau 1979). As an articulator-bound feature, we would normally expect it to pattern with other articulator-bound features, perhaps under the domination of the place node (McCarthy 1991). In any case, we would not expect it to pattern with articulator-free features such as [high] and [low]. Since [ATR] does pattern with the aperture features in Kimatuumbi, however, the suspicion is raised that this feature is being improperly used as a stand-in for a true aperture feature. In the analysis proposed here, [ATR] is replaced by a genuine aperture feature, [$open_3$].[7]

To summarize, we have seen that a feature model incorporating the hierarchical feature [open] allows a simple and straightforward expression of the Kimatuumbi rule of total height assimilation. We have also discussed some considerations suggesting that an analysis using [open] is more appropriate for the analysis of this rule than a more traditional analysis using the features [high], [low], and [ATR].

4. Scalar Height Assimilation in Nzɛbi, Esimbi and Kinande

In this section we consider a new source of evidence for the hierarchical feature [open], involving *scalar* rules: that is, rules that move vowels one step up or down along the height scale.

4.1. Nzɛbi

A first example of scalar height assimilation can be cited from Nzɛbi, a Bantu language of Gabon described by Guthrie (1968). Nzɛbi has a 7-vowel system as shown in (1a), with an additional vowel [ə], possibly deriving from /a/, occurring in positions of reduced contrast. Guthrie uses the symbols /i u e o ɛ ɔ a/ for our /i̧ u̧ i u e o a/, respectively, and we follow his usage here. This practice is strictly notational, however, and does not reflect a different feature analysis. We therefore give Nzɛbi vowels the feature interpretation in (13), identical to that of standard 7-vowel systems as given in (5a) earlier:

(13) Nzɛbi vowels:

	i u	e o	ɛ ɔ	a
open1:	-	-	-	+
open2:	-	-	+	+
open3:	-	+	+	+

Nzɛbi has a pattern of alternation in verbs conditioned by the presence of the "fleeting" suffix vowel /-i/, which is overtly pronounced only in extra-careful speech and when followed by an enclitic. This suffix markes certain verb tenses. In these tenses, the nearest nonreduced root vowel shifts up one degree in height, as shown below:

(14)	*plain*	*shifted*	*examples:*	
	e	i	-bet-/-bit(-i)	'to carry'
	o	u	-kolən-/-kulin(-i)	'to go down'
	ɛ	e	-suɛm-/-suem(-i)	'to hide self'
	ɔ	o	-tɔɔd-/-tood(-i)	'to arrive'
	a	ɛ	-sal-/-sɛl(-i)	'to work'

The vowels /i u/ do not shift, as they are already high. The rule applies both to monosyllabic roots and to roots with the suffixal extension [ə], which shifts to [i], as is shown in the second example above. According to Guthrie, all these shifts are neutralizing, and do not produce new vowel qualities. Thus the rule is structure-preserving in its effect.

Given the feature assignments given in (13), we can state the vowel raising rule as follows:

(15) Nzɛbi Vowel Raising

aperture

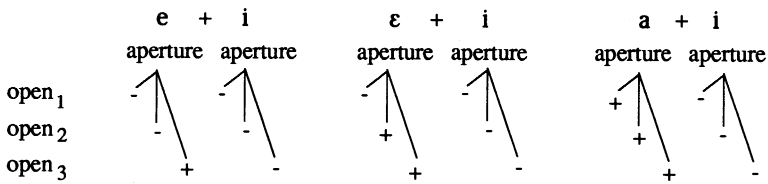
open: + -

conditions: (i) stem domain
(ii) structure-preserving

This rule states that the feature [-open] spreads leftward onto a preceding aperture node bearing the feature [+open] on the same tier. Condition (i) restricts this rule to the stem domain, and condition (ii) states that it is structure-preserving in the sense discussed above. As a result of the spreading, the original feature [+open] is deleted. Although only the "fleeting" final vowel /i/ triggers this rule, no morphological conditioning is required, since no other nonlow vowels occur in the rule context, as long as we assume that [ə] can be analyzed as underlying /a/.

What is novel about this rule in comparison with a rule like Bantu Vowel Lowering (8) is the fact that no restriction is placed on the tier on which the [+open] [-open] sequence must occur. That is, the rule is defined on [+open] [-open] sequences occurring on *any* tier in the representation, and can potentially apply to any of the tiers [$open_1$], [$open_2$], and [$open_3$]. This property of the rule, together with the structure-preservation condition, accounts for its scalar effect. To see this, consider how the rule is defined on the three underlying sequences /e–i/, /ε–i/, and /a–i/ shown below:[8]

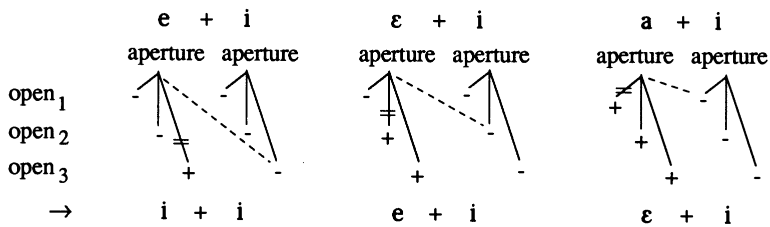
(16)



In the first of these sequences, rule (15) is defined only on tier 3; here, the fact that the rule does not mention any specific tier does not raise any problem of interpretation. But in the second and third sequence, the rule is defined on more than one tier. In each of these example, however, only one of the potential applications is structure-preserving. Thus, in the second sequence, the application of rule (15) to the [$open_2$] tier is structure-preserving since it creates the feature representation [$-open_1$, $-open_2$, $+open_3$]. This set of features characterizes [e], which occurs independently in the system. Therefore, rule (15) can apply on this tier without violating the structure-preservation condition. However, if we applied the rule to the [$open_3$] tier, the result would be a novel feature combination ([$-open_1$, $+open_2$, $-open_3$]) which does not define any independently existing vowel in the system. For similar reasons, the only structure-preserving application of rule (15) to the third example is on the [$open_1$] tier.

The full set of "legal" applications of rule (15) is given below, with "=" indicating lines deleted in the output:

(17)



This analysis captures the stepwise nature of vowel raising directly and economically, making use of a single rule of the utmost simplicity. In contrast, a feature theory making use of the features [high], [low] and [ATR] would require a complex rule and special assumptions simply in order to describe the facts. In such an analysis, the Nzɛbi vowels would have the same feature analysis as that of the corresponding Kimatuumbi vowels shown in (12). Assuming this feature analysis, the vowel shift rule would have to collapse the following three cases:

(18)	(i)	e→i, o→u:	[-ATR] → [+ATR]
	(ii)	ɛ→e, ɔ→o:	[-high] → [+high]
	(iii)	a→ɛ :	[+low] → [-low]

Under this analysis, [e o] are analyzed as [-ATR, +high] vowels. The change of [e o] to [i u] is therefore a change in the feature [ATR]. No simplification would result if we analyzed [e o] as mid, since [ATR] would then be required to distinguish the four mid vowels. The problem here is that the single rule of height assimilation must involve changes in three separate features.

These three changes can probably be collapsed with the angled bracket notation and/or the Greek-letter variables provided by standard generative phonology. However, the very fact that such powerful notational devices are required at all only emphasizes the inappropriateness of these features for expressing scalar height assimilation, a natural and widely attested rule (Clements 1991). Moreover, such an approach would be unable to explain why such special machinery is required for rules involving vowel height, and no other features. The Nzɛbi facts therefore offer strong support for analyzing vowel height in terms of the hierarchical feature [open].

4.2. Esimbi

Let us now consider a more complex case of scalar assimilation, found in Esimbi, a Broad Bantu language spoken in Cameroon. The present description is based upon a recent article by Hyman (1988), developing an earlier analysis by Stallcup (1980).

Esimbi surface vowels are presented below. Following Hyman, I use the transcription system /i u e o ɛ ɔ a/ with the same values as in Nzɛbi, together with /ɨ/ for the high central unrounded vowel found in stems. In the surface phonology, prefix vowels form a complete 4-height system, while all stem vowels are high (i.e., height 4):

(19) Esimbi surface vowels:

	prefixes:		stems:
height 4:	i	u	i ɨ u
height 3:	e	o	
height 2:	ɛ	ɔ	
height 1:	a		

This system is a highly unusual one, since in most languages, roots show more vowel contrasts than affixes.

In Hyman's analysis, which I follow in its essentials, the underlying vowel system is quite different from the surface one, especially as far as the vowel distribution is concerned. For prefixes, he proposes the reduced 2-height system /I U A/, and for stems, he proposes the 4-height system /i u e ə o ɛ ɔ a/. The four underlying stem vowel heights are neutralized at the surface by a rule assigning all stem vowels the value [+high]. Thus, all front stem vowels are realized as [i], both central stem vowels are realized as [ɨ], and all back rounded vowels are realized as [u]. This neutralization rule does not apply, however, until after the operation of a rule that *transfers* the height features of the stem vowel to the prefix. As a result of this rule, for example, the prefix vowel /I/ is realized as [i], [e], and [ɛ] after height 4, height 3, and height 1 or 2 stem vowels respectively, and the prefix vowel /U/ has the parallel representations [u], [o], and [ɔ].

These patterns are summarized in (20). Notice that in the case of the third prefix vowel /A/, each alternant is one step lower in height than the corresponding /I-/ and /U-/ alternant. We return to this fact below.

(20) Esimbi prefix alternations:

	prefix:		
surface form before:	/I-/	/U-/	/A-/
height 4 stems:	i	u	o
height 3 stems:	e	o	ɛ / __ e
			ɔ / __ o, ə
height 1 or 2 stems:	ɛ	ɔ	a

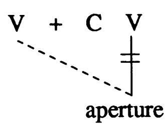
Each column gives the surface realizations of one of the prefixes before each of the vowel heights. Thus, for example, when the prefix /I-/ occurs before a stem with the height 4 vowel /i/ or /u/, it takes the form [i], when it occurs before a stem with the height 3 vowel /e/ or /o/, it takes the form [e], and when it occurs before a stem with the height 1 or 2 vowel /ɛ/, /ɔ/, or /a/, it takes the form [ɛ]. Some examples follow (tones are omitted):

(21)	height 4:	/I-bi/ →	[i-bi]	'goat'
		/I-su/ →	[i-su]	'fish'
	height 3:	/I-gbe/ →	[e-gbi]	'bushfowl'
		/I-bə/ →	[e-bɨ]	'canerat'
		/I-so/ →	[e-su]	'hoe'
	height 1/2:	/I-nyɛmɛ/ →	[ɛ-nyimi]	'animal'
		/I-zɔ/ →	[ɛ-zu]	'snake'
		/I-tla/ →	[ɛ-tlɨ]	'place'

Examining (20), we see that the surface realizations of the prefix vowels /I/ and /U/ are the result of combining their intrinsic place features (back, round) with their derived height features (as inherited from the stem vowel). Their realizations before stems with the height 1 vowel /a/ are unexpected if the low vowel constitutes an independent fourth height (since we would expect height 1 prefix vowels, not height 2 ones), and we return to this case below.

These facts, as analyzed by Stallcup and Hyman, provide strong confirmation for a model recognizing a separate height (or aperture) node. Without such a node, the spread of all height features as a unit would be arbitrary, violating the otherwise well-motivated principle that only single nodes and features can spread. With it, the analysis is straightforward: vowel height transfer shifts the aperture node from the stem vowel to the prefix vowel, as shown in (22) (intermediate nodes are omitted). We can thus view vowel height transfer as a type of total assimilation, like the Kimatuumbi rule discussed earlier.

(22) Vowel Height Transfer:



The analysis of the prefix vowel /A-/ is more complex, as the data in (20) show. Although the surface realization of this vowel is always predictable from the stem vowel, it does not involve simple height assimilation as in the case of /I-/ and /U-/. The basic observations we must account for are summarized below:

(23)	*when the underlying stem vowel is:*		*|A-| is realized as:*	
	height 4	(i u)	height 3	(o)
	height 3	(e ə o)	height 2	(ɛ / ɔ)
	height 1 or 2	(ɛ a ɔ)	height 1	(a)

In brief, the prefix vowel /A/ is realized as a vowel which is *one step lower in height* than the underlying stem vowel. (However, it is low before a low stem vowel, which follows if height 1 constitutes the "floor" in the system.)

A further irregularity in the analysis of /A/ concerns the fact that it shifts to a rounded or fronted quality before underlying stem vowels of height 3 and 4, on a partly arbitrary basis. The explanation for these shifts must be that if they did not take place, the otherwise nonoccurring surface vowels [ə] and [ʌ] would result. If this account is correct, the fact that no such shifts occur before height 1 and 2 vowels is explained by the fact that the vowel resulting directly from the stepwise lowering process, [a], occurs independently as a surface vowel. Following Hyman (p. 260), we will account for these irregular realizations in terms of secondary processes, of no consequence to the treatment of vowel height.

The problem, then, is to account for the stepwise lowering effect of the prefix vowel /A/ in a principled way. Let us give Esimbi vowels the analysis shown in (24). (As before, we include redundant values for the convenience of the reader, though these are assumed to be absent in underlying representations.)

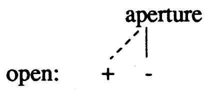
(24) feature analysis of Esimbi vowels:

	stems:			prefixes:		
	i ɨ u	e ə o	ɛ ʌ ɔ	I	U	a
$open_1$	-	-	-	-	-	+
$open_2$	-	-	+			
$open_3$	-	+	+			

This analysis treats Esimbi stem vowels as forming a 3-height system, with the height 2 vowel /ʌ/ replacing the low vowel /a/ of Hyman's analysis. This decision is well motivated on phonological grounds: the stem vowels /ɛ ɔ ʌ/ behave identically with respect to vowel height transfer, causing the prefix vowels /I, U/ to be realized as height 2 vowels and the prefix vowel /A/ to be realized one step lower as a height 1 vowel. There is no reason to distinguish these three vowels in terms of their underlying height. Under this analysis, there are no height 1 vowels in stems, and the realizations in the bottom row of (20) are entirely regular throughout.

Consider now the prefix vowel /A/, which we have analyzed analyzed in (24) as a height 1 vowel. We will assume that before Vowel Height Transfer (22) applies, this vowel triggers a rule of stepwise Stem Vowel Lowering, applying from left to right as shown below (as usual, irrelevant intermediate nodes are omitted):

(25) Stem Vowel Lowering:

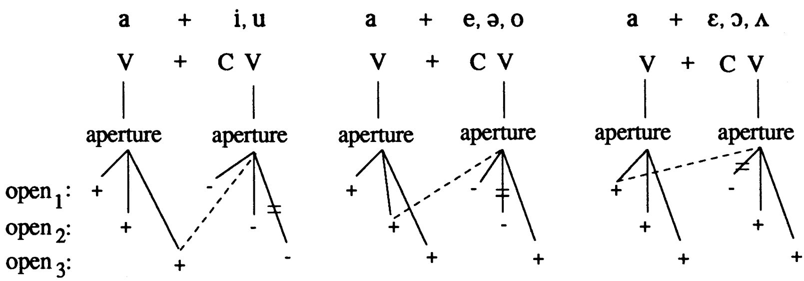


conditions: (i) word domain
(ii) structure-preserving

This rule spreads the feature [+open] rightward onto the aperture node of a vowel bearing the feature [-open]. The feature [+open] necessarily characterizes the /A-/ prefix, since no other prefix has this feature, and stem vowels have only a single-member vowel melody (cf. Stallcup). The rule cannot apply across word boundaries due to condition (i). Thus the rule is triggered only by the /A-/ prefix, and it applies only to an immediately following stem vowel.

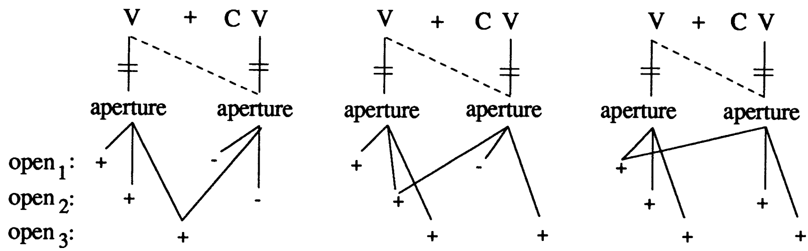
As in the case of Nzɛbi, this rule is constrained by structure-preservation (cf. condition (ii)), and no restriction is placed upon the tier on which the sequence [+open] [-open] occurs. Accordingly, the rule applies wherever it can, subject to structure-preservation. The application of (25) is illustrated below:[9]

(26)



By this rule, the aperture node of the stem vowel is lowered by one degree. The derived aperture nodes are then shifted to the prefix by Vowel Height Transfer (22), as shown below:

(27)



The aperture node of the prefix vowel, now delinked, is deleted by the general convention which eliminates floating segments created in the course of derivation. The stem vowels, lacking an aperture node, are assigned the feature [-open3] (perhaps by a default rule, as in Hyman's analysis), accounting for their surface realization as height 4 vowels.

As the reader will observe, this analysis represents the mirror image inversion of the Nzɛbi stem vowel raising rule. In Nzɛbi, a high suffix vowel raises a preceding stem vowel by one step. In Esimbi, a low prefix vowel lowers a following stem vowel by one step.

Again, as in the case of Kimatuumbi and Nzɛbi, it would be technically possible to account for these facts in terms of the standard features [high], [low], and [ATR] (or [tense]). However, such an analysis seems less than fully satisfactory, for all of the reasons cited earlier. We might consider following a suggestion by Hyman to loosen the traditional definition of [ATR] and interpret it as a third vowel height feature, whose function is to shift vowel height "register" in a manner comparable to tonal downstep. But in such a proposal, [ATR] would function quite differently from the way it functions in languages with true ATR-based vowel harmony such as Akan, where it designates the activity of the tongue root. Hyman suggests, therefore, that [ATR] might be understood as "a more general cover feature possibly involving different gestures in different languages (height, quality, pharyngealization, centralizing, flattening, etc.)" (p. 266). But such a proposal opens the door to considerable abstractness in phonological analysis. In contrast, we have seen that the hierarchical feature [open] provides a simple and direct analysis of scalar rules in Esimbi and Nzɛbi, and - by making the use of "cover features" unnecessary - allows us to maintain the strong and highly predictive position that any feature is defined in a uniform and consistent way from one language to another.

4.3. Kinande

We turn now to a discussion of a non-structure-preserving rule of scalar height assimilation found in Kinande, a Bantu language of Eastern Zaire. Kinande has a standard underlying 7-vowel system, for which we revert to the traditional transcription system /ị ụ i u e o a/. Our data are drawn primarily from the detailed study of Valinande (1985); for a description of a somewhat different variety of Kinande, see Mutaka (1991).

The rule of interest to us here is Vowel Raising, according to which vowels rise one degree in height before the height 4 vowels [ị ụ]. By this rule, the height 3 vowels [i u] are raised to the height 4 vowels [ị ụ], while the height 2 vowels [e o] are raised to the upper mid vowels [ẹ ọ], constituting a new, derived height, which we will call "height 2a." [10]

Examples are given in (28) below. Underlying representations of root vowels are given at the left. Column A shows infinitives formed from the prefix sequence /e-ri-/; here, both prefix vowels rise one step in height if the following root vowel is of height 4 (see (28a)).[11] Column B shows agentive nouns formed from the same verb roots as those given in column A. These nouns are formed with the prefixes /o-mu-/, whose underlying height 3 vowels are revealed as such by other forms like *o-mu-tahi* in which no following height 4 vowel triggers assimilation. The agentive suffix is /-ị/, with an invariant height 4 vowel. This vowel triggers stepwise raising in all vowels to its left.

(28) Kinande Vowel Raising:

		A		B	
a.	/ị/:	ẹ-rị-lịm-a	'to exterminate'	ọ-mụ-lịm-ị	'the exterminator'
	/ụ/:	ẹ-rị-hụk-a	'to cook'	ọ-mụ-hụk-ị	'the cook'
b.	/i/:	e-ri-rim-a	'to cultivate'	ọ-mụ-rịm-ị	'the farmer'
	/u/:	e-ri-hum-a	'to beat'	ọ-mụ-hụm-ị	'the beater'
c.	/e/:	e-ri-hek-a	'to carry'	ọ-mụ-hẹk-ị	'the porter'
	/o/:	e-ri-boh-a	'to tie'	ọ-mụ-bọh-ị	'the tier'
d.	/a/:	e-ri-sat-a	'to dance/play'	ọ-mụ-sat-ị	'the dancer'

The final example in (28d) seems to show that the low vowel /a/ does not undergo the rule, but allows assimilation to pass through it to the preceding prefix vowel. There are two possible ways of accounting for this fact. One, proposed by Valinande (1985), is to assume that the low vowel is transparent to assimilation, acting neither as undergoer nor blocker. The other, proposed by Hyman (1989), is to assume that the low vowel actually does undergo the rule, but is later reassigned its original value, so that the effect of the rule is cancelled out on the surface. In support of this analysis, Hyman points out that long low vowels actually do surface with the predicted raised value [ʌ:], as is shown by other forms like [o-mụ-kʌ:lị] 'woman' from the underlying stem /ka:lị/. In this analysis, only the short vowel is neutralized. For present purposes it makes no difference which of these two analyses we adopt. The important point is that the rule is scalar in effect, causing each affected vowel to rise one step in height, and non-structure-preserving, since it produces the novel vowel qualities [ẹ ọ], and perhaps [ʌ:].

Consider now how Vowel Raising can be formulated. The stepwise nature of this rule has led previous investigators to believe that it operates on the feature [ATR] (or [tense]), since these features have been described as functioning in similar ways in other languages, and are in fact the only ones available, in standard feature frameworks, to distinguish the alternating pairs of vowels. However, if we used [ATR] to distinguish the height 3 and 4 vowels in Kinande and do not also use it in other Bantu languages (such as those discussed elsewhere in this paper), we would be forced to claim that the Kinande vowel system is organized in a way fundamentally different from those of other, closely related languages. There is little or no evidence that this is true: the only relevant respect in which Kinande differs from its neighbors is that it has Vowel Raising. This minimal and quite superficial difference should not force us to postulate a fundamentally different underlying structure.

However, the hierarchical feature [open] can account for Kinande Vowel Raising rule in a straightforward way. Let us assume that Kinande vowels are underlyingly represented in the same way as in other 7-vowel Bantu languages, as shown in (5a). Vowel Raising can then be described by a rule spreading [-open3] onto the aperture node of a preceding vowel, as follows:

(29) Kinande Vowel Raising (non-structure-preserving)

```
aperture  aperture
       \ |
      -open3
```

This rule is not subject to a structure-preserving constraint. In consequence, not only will it map [i] and [u] into [ị] and [ụ], respectively, but it will map the height 2 vowels [e] and [o] into the derived "height 2a" vowels [ẹ] and [ọ]. In addition, if we allow it to apply to the low vowels, it will raise /a/ to [ʌ].

The complete set of surface vowels derived by this rule is shown below:

(30) Kinande surface vowels:

	ị ụ	i u	[ẹ ọ]	e o	[ʌ]	a
open1	-	-	-	-	+	+
open2	-	-	+	+	+	+
open3	-	+	-	+	-	+

Notice that in this system, [open3] functions in a way analogous to [ATR] or [tense] in previous analyses.

The Kinande vowel system is of particular interest to feature theory due to the fact that its pattern of alternation, involving two ranks of high vowels and two ranks of mid vowels, has previously been taken as irreducible evidence for the need for a feature like [ATR] (or [tense]). If the analysis given here is correct, it shows that patterns of this type can be created by the spread of [open] at the lowest hierarchical level, making [ATR] (or [tense]) formally unnecessary for this purpose. It remains to be seen whether other cases apparently requiring one of these features can be reanalyzed in similar terms.[12]

5. Vowel Raising in Sesotho

We now consider the 5-height vowel system of Sesotho, and show that it, too, is susceptible to a straightforward analysis in terms of the feature [open].

The Sotho group of languages, spoken in Southern Africa, are possibly unique among Bantu languages in having 5 (or perhaps 6) well-defined surface vowel heights. In addition, they have a rule of mid vowel raising which raises lower mid (height 2) vowels to a new "height 2a." Unlike the raising rules of Nzɛbe and Kinande, it is triggered not just by height 4 vowels, but by *any* higher vowel. It is this aspect of the rule that will concern us here. The discussion will be based primarily on the recent analysis of Sesotho by John Harris (1987), with further data and generalizations drawn from Doke and Mofokeng (1957), Kunene (1961), Mabille and Dieterlen (1961), and Khabanyane (1986, 1991).[13]

A chart of surface vowels is given below; a feature analysis will be proposed later. In the numbering below, vowel heights 1, 2, 3, and 4 correspond historically to those bearing the same number in other Bantu languages, while height 2a is a Sotho innovation (not corresponding to height 2a in Kinande). The following transcription uses "ẹ, ọ" instead of "ę, ǫ" for the height 2a vowels, to express the fact that the difference between "ẹ, ọ" and "e, o" is *not* parallel to the difference between "į, ų" and "i, u". The reason for this will become clear as the discussion proceeds.

(31) Sesotho vowels:

height 4:	į		ų
height 3:	i		u
height 2a:	ẹ		ọ
height 2:	e		o
height 1:		a	

Heights 2 and 2a are well-separated phonetically, having the approximate IPA values [ɛ ɔ] and [e o], respectively. There is also a further height, intermediate between 3 and 4, which will be described later.

Previous writers have suggested that the distinction between height 2 and height 2a vowels is not underlying, but arises from a rule of Mid Vowel Raising to be discussed below. I will begin by showing that at the surface level, at least, two distinct vowel series must be recognized. This is shown by minimal and near-minimal pairs such as the following:

(32) minimal and near-minimal pairs involving heights 2 and 2a:

bona	'it'	bọna	'this one'
sesefala	'to become thin'	sẹsẹbala	'to be quiet'
hlotse	'piece of dry skin or leather'	hlọtsa	'to limp'
lihotlo	'bare patch of skin on animal'	muhọtlẹ	'coot' (species)
muetse	'back, side of animal'	muẹtsọ	'way of doing'
poso	'error'	fọsa	'to err'
pere	'horse'	pẹrẹ	'pear'

Many more examples like these can be found in the extensive dictionary entries of Mabille and Dieterlen (1961); see also Khabanyane (1991) and the examples in (36) below.

The rule of Mid Vowel Raising is illustrated by the forms in (33).[14] Column A shows unraised vowels, and Column B shows their raised alternants. The forms in (33a,b) show that height 2 vowels are raised to height 2a before vowels of height 3 or 4. The forms in (33c,d) show that they are also raised before the locative suffix [-ŋ], which can be derived from a more abstract form /-i̥ŋ/, with an underlying height 4 vowel (see Harris 1987, and additional evidence cited in (43)). The examples in (33a,c) involve single vowels, and those in (33b,d) vowel sequences.

(33) Sesotho Mid Vowel Raising:

	A: unraised		B: raised	
a.	-seb-a	'gossip'	mu-sẹb-i̥	'gossiper'
	-betl-a	'sharpen'	-bẹtl-u̥w-ẹ	'has been sharpened'
	-rok-a	'praise'	si-rọk-i̥	'poet'
	-bol-a	'rot'	si-bọd-u̥	'rotten thing'
	-betl-a	'sharpen'	-bẹtl-i	'not to sharpen'
	-ep-a	'dig'	-ẹp-ul-l-a	'dig out'
	-bon-a	'see'	-bọn-i	'to have seen'
	-kob-a	'bend'	-kọb-ul-l-a	'unbend'
b.	-kob-eh-el-a	'curve towards'	-kọb-ẹh-ẹl-i	'not to curve towards'
	-hlek-eh-a	'become clear'	-hlẹk-ẹh-i̥lẹ	'to have become clear'
	-hlohlon-a	'itch'	-hlọhlọn-i	'not to itch'

c.	lisapo	'bone'	lisapọ-ŋ	(locative)
	kopano	'meeting, assembly'	kopanọ-ŋ	(locative)
d.	sihole	'deformed person'	sihọlẹ-ŋ	(locative)
	theko	'price'	thẹkọ-ŋ	(locative)
	pepenene	'open space'	pẹpẹnẹnẹ-ŋ	(locative)

There is evidence that not only height 3 and 4 vowels, but also height 2a vowels trigger Mid Vowel Raising. This point is somewhat harder to demonstrate, since most surface occurrences of height 2a vowels are created by Mid Vowel Raising itself. However, the very fact that the rule applies iteratively gives us a first argument for this view. Under iterative application, it first applies to the last member of a sequence of potential target vowels, changing e.g. underlying /-kob-eh-el-i/ to [-kob-eh-ẹl-i]. In subsequent iterations, the derived vowels [ẹ] trigger new applications of the rule to preceding vowels, giving the surface form [-kọb-ẹh-ẹl-i]. It is the second (and subsequent) applications of the rule that show that height 2a vowels are themselves triggers for the reapplication of the rule.

Let us briefly consider a possible alternative analysis which does not require iterative rule application. In this alternative, the two mid vowels would be viewed as sharing a single aperture node as a result of the Obligatory Contour Principle (OCP) (McCarthy 1986), which, in its most general formulation, disallows adjacent identical nodes on any tier. In the present case, this principle would disallow two adjacent identical aperture nodes, and cause them to be collapsed into a single one. As a consequence, the vowel sequence in the stem /tetem-/ would share a single aperture node, as shown below:

```
(34)      ...  e        t      e  ...
             vocalic     vocalic
                   \    /
                  aperture
```

Mid Vowel Raising could then apply in a single step, in which case it would not offer any crucial evidence that height 2a vowels can be rule triggers.

While this analysis is a possible one, there is some evidence that the OCP does not operate as a general constraining principle in the segmental phonology of Sesotho. Harris (1987) shows that Sesotho has a rule which deletes high front vowels between a voiced coronal and any following coronal. This rule can be stated roughly as follows (using standard features):

(35) I- Deletion

[-cons, +high, -back] → Ø / [+cor, +voiced] ___ [+cor]

This rule creates OCP violations at the level of the entire segment (i.e., the root node) in examples like nọn-ịn-e → nọn-n-e [nọn̥nẹ] 'be fat', derived from underlying /non-ịl-e/ via a rule of nasal assimilation. It also creates OCP violations at the level of the feature [coronal] in examples like bọn-ịs-a → bọn-s-a → [bọn̥tsha] 'show', derived from underlying /bon-ịs-a/. Such examples show that if the OCP applied to the aperture tier, it would be as a special case, since OCP violations are tolerated elsewhere. While an OCP-based analysis of vowel sequences cannot be ruled out in principle, there is little or no independent evidence showing that the OCP operates elsewhere in Sesotho.[15]

A second argument that height 2a vowels can trigger Mid Vowel Raising comes from a general restriction on surface vowel sequences, according to which height 2 vowels do not cooccur with height 2a vowels in adjacent syllables. This constraint applies not only to height 2a vowels created by Mid Vowel Raising, but also to height 2a vowels occurring in contexts where Mid Vowel Raising is not defined, as in word-final position. Several examples of the latter type were given in (32), and further examples are given below:

(36)	thẹpẹ	'kind of vegetable'	sihlẹkẹhlẹkẹ	'island'
	lẹlẹlẹ	'long, tall'	mukọlọkọ	'procession'
	maɲọlọ	'fertilizer'	liqịtọlọ	'one with tricks'
	sibẹlẹ	'rumor'	shwẹshwẹ	'type of wild flower'

Such examples show that if a height 2a vowel occurs anywhere in a mid vowel sequence, all vowels in that sequence must be height 2a. Thus we do not find "mixed" sequences like *[ẹ...e], *[ọ...o], *[e...ẹ], and so forth. If we assumed that *all* height 2a vowels were underlying in such examples, it would be a striking and unexplained accident that "mixed" height 2 and 2a sequences do not occur. At best, we could rule them out with a special word structure constraint, replicating the conditions under which Mid Vowel Raising applies. If instead we assume that the word-final height 2a vowels illustrated in (36) are underlying (or possibly created by other rules operating before Mid Vowel Raising), and that they trigger Mid Vowel Raising in preceding height 2 vowels, we account for the absence of mixed sequences in a principled way. Thus if this analysis is correct, height 2a vowels must be Mid Vowel Raising triggers.[16]

To summarize the discussion so far, we have seen evidence that Mid Vowel Raising raises height 2 vowels to height 2a when followed by a vowel of height 2a, 3, or 4 in the next syllable. In a nutshell, it raises height 2 vowels by one degree when followed by any higher vowel. How can we express this generalization in feature terms?

We can provide a direct answer to this question if we assume that the feature analysis given earlier for the basic vowel heights 1, 2, 3, and 4 in other Bantu languages holds for Sesotho as well, as shown by the specifications for [open$_{1\text{-}3}$] in (37) below. Height 2a results from the split of the lower of the two secondary registers into a further pair of subregisters (in the sense of figure 1), opposing the upper mid vowels to the lower mid vowels. We define this new pair of subregisters in terms of a new [open] tier, which, as it characterizes the least contrastive vowel height in the system (i.e., the one most subject to neutralization), is assigned the lowest rank 4. This gives us the following analysis, in which redundant values are once again filled in for clarity.

(37) Sesotho vowels:

height:	4	3	2a	2	1
	į ų	i u	ẹ ọ	e o	a
$open_1$	-	-	-	-	+
$open_2$	-	-	+	+	+
$open_3$	-	+	+	+	+
$open_4$	-	-	-	+	+

The class of all vowels that are higher than height 2 is a natural class, defined by the feature [-$open_4$]. We can state Mid Vowel Raising as follows:

(38) Sesotho Mid Vowel Raising (structure-preserving):

aperture aperture

[-open]$_4$

This rule is structure-preserving, since it only creates vowels that already exist in the rule's input. This means that it cannot apply to low vowels, since if it did, it would create a new, previously nonoccurring series of upper low vowels ("height 1a"). For this reason, it is not necessary to explicitly restrict the set of target vowels to [-$open_1$] (nonlow) vowels.[17]

Once again, it would be possible to describe the Sesotho facts in terms of a standard feature system making use of the features [high], [low], and [ATR] (or [tense]). But such an analysis is less straightforward. Suppose we were to assume an analysis like that given in (12) for Kimatuumbi, with the height 2a vowels constituting an additional, [+ATR] series of mid vowels:

(39) Sesotho vowels (using standard features):

height:	4	3	2a	2	1
	ị̜ ụ̜	i u	ẹ ọ	e o	a
low	-	-	-	-	+
high	+	+	-	-	-
ATR	+	-	+	-	-

This analysis cannot identify the spreading node in Mid Vowel Raising as a natural class. The feature [+high] will not do, since if [+high] spreads it will incorrectly map height 2 into height 3, instead of height 2a. The feature [+ATR] will not do either, since it will not account for the fact that height 3 vowels are also triggers.

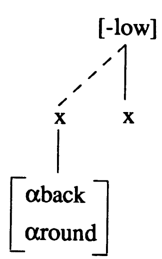
We could solve this problem if we reanalyzed /e o/ as low, rather than mid vowels, as proposed by Harris. In this case, the feature [ATR] would be distinctive only in the class of high vowels, and the feature chart would become the following:

(40) Sesotho vowels (after Harris 1987):

height:	4	3	2a	2	1
	ị̜ ụ̜	i u	ẹ ọ	e o	a
low	-	-	-	+	+
high	+	+	-	-	-
ATR	+	-			

In this analysis, the spreading node is [-low], and the raising rule can be stated as follows:

(41) Mid Vowel Raising (Harris 1987):



This statement requires the target vowel to agree in [back] and [round]; the rule thus applies to /e/ and /o/, but not /a/.[18]

While this analysis can account for the data, it is less satisfactory than an analysis involving [open], on several counts. First, the treatment of /e/ and /o/ as [+low] vowels is motivated only by the rule in question. This analysis has no further phonological motivation, since /a/ does not otherwise pattern with the height 2 vowels as a class. Nor does this treatment have any phonetic motivation, since /e/ and /o/ have the phonetic values [ɛ] and [ɔ], not [æ] and [ɒ], and there is a considerable difference in first formant frequency between /a/ and /e, o/ (see Khabanyane 1991). We could account for this discrepancy by late realization rules assigning /ẹ ọ/ the surface features [+ATR,-low] and /e o/ the features [-ATR, -low] for instance, but such rules only underscore the point that the phonological analysis does not mesh with the observed phonetic realizations.

Similar remarks extend to the use of [ATR], which is being used here as a "cover feature" in the sense discussed earlier in connection with Esimbi. As far as the acoustic evidence is concerned, Sesotho gives no grounds for treating the five phonemic vowel heights in terms of anything but a uniform phonetic parameter of vowel height. All vowels tend to be of equal duration in similar contexts, and fall along a single, uniform scale as far as first and second formant values are concerned (see Khabanyane). In classical ATR-based systems, such as that of Akan, the [+high, -ATR] vowels are not well separated in first formant frequency from the [-high +ATR] vowels (Lindau 1975). Furthermore, Sesotho does not have a system of "cross-height" vowel harmony pairing its different vowel heights into overlapping sets, as do Akan and many other languages for which [ATR]-type harmony has been reported.

In the context of the comparative focus adopted in this study, an analysis in which /e o/ are treated as low vowels is at odds with the analysis required on independent grounds for other Bantu languages. We have seen that in Nzɛbi and Esimbi, and perhaps Kinande as well, the relation of /a/ to /e, o/ is parallel to that of /e, o/ to /i, u/: the scalar raising and lowering rules treat /a/ as the lowest point on a scale of vowel height on which /e, o/ constitute the next step. This relation is not defined in a system in which /e, o/ are assigned the same height as /a/; in Sesotho, such a treatment would ultimately be motivated by only a single rule in the language.

In contrast, we have seen that a hierarchical feature model using the feature [open] permits an analysis of Sesotho which is simple, close to the phonetics, and consistent with the analyses of other Bantu languages. In this analysis, the core system of Sesotho (and that of other Sotho languages, which are similar in relevant respects) consists of its height 1, 2, 3, and 4 vowels, characterized in exactly the same way as the historically cognate vowel heights in other Bantu languages.

Sesotho bears out two interesting predictions of the hierarchical feature model that we have not previously discussed. First, the model predicts that we should be able to find rules that make reference to the class of vowels that are "higher than" (or alternatively, "lower than") some other set of vowels. This is because for each vowel height, the system provides a way of designating this class. This prediction is borne out by Mid Vowel Raising, which refers to the class of all vowels "higher than" height 2.

Second, the model predicts that hierarchical subdivision is open-ended, in the sense that there is no *formal* upper limit on the number of tiers to which [open] can be assigned. The earlier study of 4-height Bantu vowel systems has shown that this number may be three, but Sesotho shows that it may be greater than three.

In fact, there is some evidence that Sesotho is in the process of undergoing yet a *further* phonological split, creating a fifth [open] tier. As described by Kunene (1961) and Khabanyane (1986), a rule of High Vowel Raising raises height 3 vowels to a new height 3a, intermediate between heights 3 and 4. This rule applies to vowels under the following conditions:

(42) a. preceding a syllable containing one of the vowels [į ų] of height 4;
b. preceding the locative suffix [-ŋ] (derived from /-įŋ/);
c. following a syllable containing one of the height 4 vowels [į ų] of identical backness to the affected vowel.

Some examples illustrating these cases are given below:

(43) a. -bila 'boil' -bịdįlẹ (perfect) -bịdįsa (causative)
-nuka 'season' -nụkįlẹ (perfect) -nụkįsa (causative)

b. sibi 'sin' sįbị-ŋ (locative)
buhuluhulu 'long ago' bụhụlụhụlụ-ŋ (locative)
sirupi 'thigh' sįrụpị-ŋ (locative)

c. mụrįfị 'clay pot'
-rųmụla 'tease, provoke'
-phųthụlụha 'become unfolded'

The distinction between the corresponding height 3a and 4 vowels is a subtle one, even for listeners with phonetic training. Acoustic measurements show mean first formant differences between corresponding height 3a and 4 vowels ranging between 20 and 80 Hz (Khabanyane, 1991). However, these differences, though small, are apparently perceptible. In the very similar vowel system of Tswana, Cole reports that minimal pairs such as [-bįdįtsẹ] 'call' (perfect stem) and [-bịdįtsẹ] 'beat' (perfect stem) are reliably distinguished by native speakers (Cole 1949, 115). One might expect comparable pairs to be distinguishable in Sesotho.

Given the subtlety of the distinction between height 3a and 4 vowels, one might ask whether the height 3a vowels arise through a rule of phonetic implementation, rather than a feature-changing phonological rule. If this were the case, they would have no direct bearing on phonological feature models. Some evidence for a phonetic rule analysis might be suggested by Khabanyane's observation (1986) that in some contexts, High Vowel Raising does not seem to affect the first in a string of several vowels. This might suggest that we are dealing with a gradient implementation rule whose "window" extends over several syllables, affecting vowels most strongly at the end of the domain but only weakly, if at all, at the beginning.

In spite of this observation, further evidence suggests that High Vowel Raising may be truly phonological in nature. As we have seen, this rule applies before height 4 vowels and the nasal suffix [-ŋ], though not before other high consonants, such as velar stops. On the surface, these segments do not form a natural class. However, we have already remarked that the nasal can derived from the more abstract sequence /-ịŋ/ at a point in the derivation following the application of Mid Vowel Raising. We can explain the fact that [-ŋ] triggers High Vowel Raising if we assume that it still has the representation /-ịŋ/ at the point at which this rule takes place. On this analysis, High Vowel Raising would triggered by the natural class of high vowels [ị ụ] alone. On the widely-held assumption that phonological rules precede phonetic implementation rules, this would argue that High Vowel Raising is a phonological rule, since it crucially precedes the phonological rule reducing /-ịŋ/ to syllabic [ŋ].

There is further evidence that High Vowel Raising may be phonological in nature, which I cite quite tentatively in the absence of strict phonetic verification. This evidence comes from certain forms noted by Khabanyane (1986). The negative suffix /-i/, illustrated earlier in several examples in (33), is realized as [-ị] under the following conditions:

(44) a. before a noun object:

	hu si phụphụth-ị muthu	'not to shake off a person'
	ha a kụp-ị mme	'he does not ask mother'

b. after a vowel of height 4:

	hu sị ịs-ị	'not to take away'
	hu sị dụl-ị	'not to sit'

Elsewhere, though still triggering High (and Mid) Vowel Raising, it is realized as [-i]:

(45)	hu si phụphụth-i	'not to shake off'
	ha a kụp-i	'he does not ask'
	hu si sẹb-i	'not to gossip'
	hu si kọkọt-i	'not to knock'

What is curious is that the suffix triggers High Vowel Raising in such examples even when it is realized as the lower vowel [i]. In one possible analysis, the basic value of the suffix could be taken as /ị/, which triggers High Vowel Raising in preceding height 3 vowels in all contexts, and is subsequently lowered to [-i] after lower vowels in absolute phrase-final position. If these admittedly subtle facts can be confirmed, they offer further evidence that height 3a vowels may be phonological in nature: not only does High Vowel Raising precede another phonological rule (in this case, phrase-final lowering), but the vowel /ị/ is underlying, or derived by an early morphologically-conditioned rule.

If High Vowel Raising is a true phonological rule involving phonological features, it is clear that no possible combination of the standard features [high], [low], and [tense]/[ATR] can give a straightforward account of the height 3a vowels. In contrast, the hierarchical model can account for them by allowing [open] to occur on a fifth tier, as follows:

(46) Sesotho surface vowels:

height:	4	3a	3	2a	2	1
	i̭ ṷ	ị ụ	i u	ẹ ọ	e o	a
$open_1$	-	-	-	-	-	+
$open_2$	-	-	-	+	+	+
$open_3$	-	+	+	+	+	+
$open_4$	-	-	-	-	+	+
$open_5$	-	-	+	+	+	+

In this analysis, height 3 vowels are distinguished from height 3a vowels by the feature [$open_5$]. High Vowel Raising can now be expressed as the spread of the feature [-$open_5$] to from height 4 vowels to height 3 vowels.

To conclude this discussion of Sesotho, let us consider whether it is possible to collapse Mid Vowel Raising and High Vowel Raising into a single, comprehensive rule raising any nonlow vowel one degree in height before a higher vowel (cf. a similar suggestion by Ladefoged 1989). Elegant as such a proposal might appear, it is contradicted by the fact that the nonderived mid vowels /ẹ ọ/ are not raised before higher vowels. This is shown by representative examples like the following (Kunene 1961, Mabille and Dieterlen 1961):

(47) nonderived /ẹ ọ/ followed by higher vowels:

a. ẹts-a 'do':

mu-ẹts-i̭	'doer'
mu-ẹts-ṷwa	'victim'
ẹts-ịs-a	'cause to do'
ẹts-ul-l-a	'to undo'

b. fọs-a 'err':

mu-fọs-ị	'one who errs'
bu-fọs-ị	'fallibility'
mu-fọs-ụwa	'one at the prejudice of whom a mistake has been committed'
fos-ịs-a	'cause to miss'

Note that the height 2a vowels in these stem cannot be derived by Mid Vowel Raising, since they do not occur in the context for this rule. The consonants /ts, s/ do not provide a regular raising context, as we see from examples like *hlesa* 'to shiver', *poso* 'error', *khoso* 'string of beads worn around the loin', *sesefa* 'to avoid', *sosobana* 'to become wrinkled or creased', *bokotsa* 'to pat', *hlotse* 'piece of dry skin or leather', *kxhotso* 'peace', etc. Many other examples confirm the fact that heights 2a vowels are not raised before higher vowels. For example, the relative (or pronominal) prefixes have height 2a vowels to the exclusion of all other nonlow vowels. These vowels do not shift in height, whatever the height of the following vowel: cf. *ẹ-chịtja* 'hornless' (class 9), *ọ-muhulu* 'big' (class 3).

In addition to these facts, Mid Vowel Raising applies under a variety of morphological conditions which do not govern High Vowel Raising (see the references in note 14). It thus seems that we are dealing with two independent rules, Mid Vowel Raising and High Vowel Raising, which happen to overlap in their domain of application.

6. Alternative Theories of Vowel Height

We have seen reasons in the preceding discussion to believe that vowel height assimilation rules of the sort found in Bantu languages cannot be adequately treated in terms of the standard features [high], [low], and [ATR]. In this section we consider whether these rules might be better treated in other (nonhierarchical) feature theories.

Stepwise (or scalar) raising and lowering rules have occasionally been cited as evidence for multi-valued features (e.g. Johnson 1972, Lindau 1978). Specifically, it has been suggested that vowel height can be described in terms of a single, multivalued feature [*n*High]. In such theories, a rule such as Nzεbi Vowel Raising (15) might be expressed as in (48):

(48) $V \rightarrow$ [n+1 High] / __ [4 High]

This rule states that a vowel rises one step in height before a height 4 vowel.

One important difference between a multivalued feature theory and the binary, hierarchical model proposed here involves their different implications for the formal description of assimilation. In autosegmental theory, assimilation is expressed as feature spreading, as we have seen; no other formal treatment is available (Clements 1985).

However, rules like (48) do not express partial assimilation as autosegmental spreading, since they simply respecify one feature in the context of another, formally unrelated one. More problematically, we cannot restate this rule in terms of autosegmental spreading, since spreading [4High] from one vowel to another carries out total, not partial assimilation; it would cause all vowels to become [4 High] in the context of another [4 High] vowel. Nor can we spread the values 1, 2,... independently of each other, since they are not independent features but *specifications* of the feature [High], and cannot spread independently of the feature [High] itself. There is thus no way to express partial height assimilation (whether scalar or nonscalar) as autosegmental spreading in multivalued feature frameworks as they are currently formulated.[19]

Moreover, rules such as "V → [n+1 High]" cannot express non-structure-preserving vowel raising rules like that of Kinande in a straightforward way. In effect, such rules would have to map not only height 3 vowels onto height 4, but also height 2 vowels onto a new height 2a (and perhaps height 1 onto a new height 1a, depending on our analysis of the low vowel). The computational machinery require to carry this out would be arbitrary and quite unconstrained. Alternatively, one might propose to regard the underlying vowel heights of Kinande as forming a discontinuous scale (6, 5, 3, 1), but there is no independent evidence for such an analysis. As a last resort, the feature [ATR] could be used as an abstract "cover" feature to supplement the multivalued feature [High], but it would then be available to express all other types of scalar vowel raising as well, making the multivalued specifications of [High] entirely superfluous.

The stepwise raising and lowering rules described above also raise problems for one-valued feature theories such as those proposed in particle theory (Schane 1984) and dependency phonology (Anderson and Ewen 1987). In such theories, vowel height is expressed in terms of a one-valued feature *a* (usually called a particle, or component) designating vocal tract opening. In such theories, scalar lowering could be expressed by allowing more than one occurrence of *a* in the representation of a given vowel. The Esimbi rule, for example, could add a token of *a* to any stem vowel occurring after the prefix /A-/. However, as one-valued feature theories do not recognize any features corresponding to [+high] or [-open], they have no way of expressing scalar raising rules (or indeed, any kind of assimilatory raising rules!) in terms of the same formal mechanisms used elsewhere for the expression of assimilation. As a result, such theories strongly predict that raising rules such as those of Nzεbi, Kinande, Sesotho, and many other languages should not exist.

We have seen, in contrast, that the hierarchical feature [open] can provide a simple, direct account of a variety of assimilatory raising and lowering rules in Bantu languages, while preserving a uniform system of underlying feature representation for Bantu vowels.

7. Summary and Discussion

This study has argued for a new theory of vowel height, based on data from Bantu languages. In this model, vowel height is characterized along a uniform phonetic and phonological dimension, represented in terms of the binary feature [open]. This feature is *hierarchical* in the sense that it maps onto sets of successively embedded registers and sub-registers. The rank of the tier on which [open] is arrayed determines the hierarchical level of the height register onto which it maps. As a hierarchical feature, [open] differs from most other phonological features, with the possible exception of [high tone], which has sometimes been characterized in similar hierarchical terms (Clements 1983, Hyman 1986).

While individually, any of the Bantu systems discussed in this study could be described by other feature systems with a greater or lesser degree of arbitrariness, taken together, they provide a powerful argument for the hierarchical model. A highly desirable result of the present study is that it has succeeded in providing a uniform way of characterizing Bantu vowels at the level of underlying representation, treating surface divergences as the result of historical or synchronic assimilation rules. It seems appropriate that groups of genetically and typologically related languages should be characterized in such a way as to bring out their fundamental structural unity, especially when this unity is not imposed on them by arbitrary analysis, but follows deductively from an appropriately-chosen model.

In contrast to the traditional descriptivist view that "each language must be described in its own terms," that is without respect to the structure of closely related languages, we may propose that closely related languages will, in a fully adequate analysis, display an important shared core of basic features of structure, perhaps expressible as shared parameter choices in the most general sense of this term. In phonology, for instance, these might take the form of a shared set of underlying feature categories, or a common core of similar lexical rules, applying under similar conditions. Differences at more superficial levels of structure will result largely from divergences in the rule system, increasing in importance as we proceed from earlier to later rule strata. Such a comparative perspective proves to be appropriate and revealing when applied to the analysis of the Bantu languages, which form a homogenous unit comparable in their basic structural similarity to e.g. the Romance or Chinese languages. Linguistic theories which allow us to bring genuine, deep-seated relationships of this sort to light should be preferred to those that force us to postulate different, unrelated analyses of fundamentally similar phenomena. The hierarchical model of vowel height proposed here seems to represent an improvement over earlier feature models in just these terms, since it makes it possible to attribute a common shared system of vowel features to an interesting variety of Bantu vowel systems, many of whose differences can be attributed to fairly superficial aspects of their rule systems.

The theory of vowel height presented here, if correct, has several consequences for feature theory. We have seen considerable evidence that it provides a better alternative for the characterization of vowel height than do the standard features [high], [low], and [ATR] (or [tense]). These results should encourage a reexamination of the appropriateness of the standard features for analyses of other languages and language groups. We have also seen that the hierarchical model provides a more adequate treatment of vowel height than alternative models making use of a multivalued feature [*n*High] or a one-valued feature (or particle) *a*. It appears that vowel height is in fact best viewed as a binary feature, but one that can be arrayed on multiple tiers.

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Notes

1 This rule extends to prefixes in a few languages (e.g. Gusii, Llogoori), probably as an innovation. Also, [u] lowers to [o] after [e] in some languages (e.g. Kongo), also probably as an innovation. The fact that [u] generally assimilates only after [o] and not [e] may reflect a crosslinguistic tendency according to which one segment, A, is more likely to assimilate to another segment, B, to the extent that A and B have more features in common (Kiparsky 1988).

2 The present study forms part of a larger work in progress, in which the model is extended to a wider range of phenomena (Clements 1990, 1991).

3 In most 4-height languages, however, the system of verb suffixes involves a contrast among four or five vowels. Thus in Kikuyu, for example, the vowel of the causative suffix /-i̯/ contrasts with the vowel of the applied suffix /-ir/ both in intrinsic height, and in failing to lower after height 2 vowels (see e.g. *ɣu-ðer-i̯-a* 'to cleanse'); the same is true of the current past completive tense suffix /-i̯re/ (e.g. *tu-ror-i̯re* 'we looked at').

4 Odden (1989) gives further evidence in support of separate place and aperture nodes for vowels.

5 In a possible alternative analysis, we might regard /a/ as the default vowel in Bantu in the sense of Archangeli (see e.g. Archangeli 1984, 1988). In such an analysis, /a/ would be entirely featureless, and would receive its surface features by default rules

would be entirely featureless, and would receive its surface features by default rules inserting [+open$_1$], [+open$_2$] and other relevant features. Having no height features, /a/ would have no aperture node and could not serve as a trigger in the rule, allowing us to eliminate the mention of [-open$_1$] from its context. This analysis would explain quite elegantly why low vowels do not have a lowering influence on other vowels. A problem, however, is that under Archangeli's other assumptions, rule (8) should trigger the RROC (Redundancy Rule Ordering Constraint), which requires that a redundancy rule inserting feature [αF] applies before any rule mentioning [αF]. Given this principle, rule (8) should require the prior application of the redundancy rule introducing [+open$_2$] in low vowels, and we would still have to explicitly exclude low vowels from the class of triggers.

6 Recall that since consonants do not have aperture nodes, they will not block the application of this rule.

7 I leave open the question of whether [ATR] ever patterns with place features in other languages. If it does not, one must question whether [ATR] is justified as an independent phonological feature, distinct from [open] on the one hand and [radical] or [constricted pharynx] on the other.

8 The following derivations crucially require that the rules inserting the redundant features [+open$_2$] and [+open$_3$] under the aperture node of /a/ apply before rule (15) does. This effect is predicted by the RROC, mentioned in note 5.

9 As in the case of Nzεbi (see note 8), the redundancy rules assigning the features [+open$_2$] and [+open$_3$] must apply before this rule does.

10 In the variety of Kinande described by Valinande (1985), Vowel Raising applies bidirectionally, subject to the same conditions in both directions. In the variety described by Mutaka (1991), Vowel Raising applies rightward only under a more restricted set of conditions. These differences, whether individual or dialectal, do not appear to have any consequences for the feature analysis of Kinande. They will accordingly be disregarded in the following discussion, which focuses on the leftward case.

11 In the variety of Kinande described by Mutaka (1991), word-initial vowels are only optionally affected by the raising rule.

12 Another Bantu language reported to have ATR-like vowel harmony is Tunen (see van der Hulst et al. (1986) and references therein).

13 The Sotho languages include Tswana, Northern Sotho, and Sesotho (also known as Southern Sotho); see Tucker (1929) and Doke (1954) for general descriptions of the group as a whole. While the present discussion concerns the particularly well-documented case of Sesotho, nearly identical vowel systems are found in the other Sotho languages. For fuller discussion of Tswana see Cole (1949, 1955), and for

Northern Sotho see Ziervogel (1967). In the earlier stages of preparing the present account, I had the benefit of many discussions of Sesotho phonology with Evelyn Khabanyane, a resident of Motsethabong district, Welkom, South Africa, who is the author of the phonetic and phonological studies cited in the text..

14 Mid Vowel Raising applies under a complex variety of conditions, some of which are purely phonological and some of which are morphological. We will be concerned here only with the phonological environments, in which height 2 vowels are raised to height 2a when a higher vowel follows in the next syllable. See Doke and Mofokeng (1957) and Kunene (1961) for more complete descriptions.

15 See Odden (1988) and Yip (1988) for further discussion of the OCP, and evidence that it does not operate as an automatic mechanism eliminating OCP violations wherever they arise.

16 The facts are slightly more complicated than stated above, in ways that do not affect the main point. By a separate rule, a height 2a vowel triggers the raising of a following height 2 vowel, as in *ẹts-a* 'do', *kẹts-ọ* 'deed', *ẹts-ẹh-ịle* 'to be practicable'. This rule does not apply to a vowel in the penultimate syllable, as shown by *ẹts-eh-a* 'to happen' and similar examples (Doke and Mofokeng 1957). Thus it would also be possible to account for the examples in (36) by postulating a height 2a vowel in the penultimate syllable, which triggers spreading both leftward and rightward. Even in this analysis, however, height 2a vowels would have to be Mid Vowel Raising triggers to account for its application in longer sequences such as those in *mukọlọkọ*, etc.

17 Harris (1987) argues that Mid Vowel Raising is a non-structure-preserving rule, since he views the height 2a series as entirely derived. However, I have given evidence above that this series occurs underlyingly. Specifically, examples such as those in (32) and (36), and many others of the same sort not considered by Harris, offer reason to believe that height 2a vowels are already present in representations at the point at which Mid Vowel Raising applies in the synchronic grammar. (Of course, the rule may have applied in a non-structure-preserving fashion at an earlier historical stage of the language, a point not at issue here.)

18 This restriction is required in Harris's analysis, since, as we have remarked in note 17, he regards this rule as non-structure-preserving. Since we have shown the height 2a vowels to occur in the input to this rule, however, we could regard the rule as structure-preserving. This will allow us to eliminate the [αback, αround] condition, since the rule will not be able to assign [-low] to /a/ without violating the structure-preservation condition (nonlow vowels must be front or rounded). With this modification, Harris's rule is comparable to the one in (38) in terms of formal simplicity.

19 This argument is originally due to Hayes (1990).

References

Anderson, J.M. and C.J. Ewen (1987) *Principles of Dependency Phonology*, Cambridge University Press, Cambridge.

Archangeli, D. (1984) Underspecification in Yawelmani Phonology and Morphology, Ph.D. dissertation, MIT, published 1985 by Garland Publishing Co., N.Y.

Archangeli, D. (1988) "Aspects of Underspecification Theory," *Phonology* 5.2, 183-208.

Clements, G.N. (1983) "The Hierarchical Representation of Tone Features," in I.R. Dihoff, ed., *Current Approaches to African Linguistics* vol. I, Foris Publications, Dordrecht, 145-176.

Clements, G.N. (1985) "The Geometry of Phonological Features," *Phonology Yearbook* 2, 225-52.

Clements, G.N. (1987) "Toward a Substantive Theory of Feature Specification," in *Proceedings of NELS 18*, 79-93.

Clements, G.N. (1990) "The Hierarchical Representation of Vowel Height," unpublished ms., Cornell University, Ithaca, N.Y.

Clements, G.N. (1991) "Scalar Rules in Phonology," paper presented at the 2nd Annual Conference of the Formal Linguistics Society of Midamerica (FLSM), University of Michigan, Ann Arbor.

Clements, G.N. (in press) "Place of Articulation in Consonants and Vowels: a Unified Theory," in B. Laks and A. Rialland, eds., *L'architecture des représentations phonologiques,* Editions du C.N.R.S., Paris. [in this issue]

Cole, D.T. (1949) "Notes on the Phonological Relationships of Tswana Vowels," *African Studies* 8.3, 109-131.

Cole, D.T. (1955) *An Introduction to Tswana Grammar*, Longmans, Green & Co.

Doke, C.M. (1954) *The Southern Bantu Languages,* Oxford University Press, London.

Doke, C.M. and S.M. Mofokeng (1957) *Textbook of Southern Sotho Grammar*, Longman, Johannesburg.

Greenberg, J. (1951) "Vowel and Nasal Harmony in the Bantu Languages," *Zaïre* 5.8.

Guthrie, M. (1968) "Notes on Nzɛbi (Gabon)," *Journal of African Linguistics* 7.2, 101-29.

Harris, J. (1987) "Non-structure-preserving Rules in Lexical Phonology," *Lingua* 72.4, 255-292.

Hayes, B. (1990) "Diphthongization and Coindexing," *Phonology* 7.1, 31-71.

Hulst, H.G. van der, M. Mous, and N. Smith (1986) "The Autosegmental Analysis of Reduced Vowel Harmony Systems: the Case of Tunen," In F. Beukma and A. Hulk, eds., *Linguistics in the Netherlands 1986,* Foris Publications, Dordrecht, pp. 105-122.

Hyman, L.M. (1986) "The Representation of Multiple Tone Heights," in K. Bogers, H. van der Hulst, and M. Mous (eds.) *The Phonological Representation of Suprasegmentals,* Foris Publications, Dordrecht, pp. 109-52.

Hyman, L.M. (1988) "Underspecification and Vowel Height Transfer in Esimbi," *Phonology* 5.2, 255-73.

Hyman, L.M. (1989) "Advanced Tongue Root in Kinande," unpublished ms., U.C. Berkeley.

Johnson, C. D. (1972) *Formal Aspects of Phonological Description,* Mouton, The Hague and Paris.

Khabanyane, K.E. (1986) "Southern Sotho Vowel Raising," unpublished paper, Cornell University.

Khabanyane, K.E. (1991) "The Five Phonemic Vowel Heights of Southern Sotho: an Acoustic and Phonological Analysis," ms., Cornell University. [in this issue]

Kiparsky, P. (1985) "Some Consequences of Lexical Phonology," *Phonology Yearbook* 2, 85-138.

Kiparsky, P. (1988) "Phonological Change," in F.J. Newmeyer, ed., *Linguistics: the Cambridge Survey,* vol. 1: *Linguistic Theory: Foundations*, Cambridge University Press, Cambridge, 363-415.

Kunene, D.P. (1961) The Sound System of Southern Sotho, unpublished Ph.D. dissertation, University of Cape Town.

Ladefoged, P. (1989) Representing Phonetic Structure, *UCLA Working Papers in Phonetics* 73, 1-79.

Lindau, M. (1975) Features for Vowels *(UCLA Working Papers in Phonetics,* 30.), UCLA, Los Angeles.

Lindau, M. (1978) "Vowel Features," *Language* 54.3, 541-63.

Lindau, M. (1979) "The Feature Expanded," *Journal of Phonetics* 7, 163-176.

McCarthy, J. (1986) "OCP Effects: Gemination and Antigemination," *Linguistic Inquiry* 17, 207-63.

McCarthy, J. (1991) "The Phonology of Pharyngeal Articulations in Semitic," paper presented at the 3rd Conference on Laboratory Phonology, UCLA, Los Angeles.

Mabille, A. and H. Dieterlen (1961) *Southern Sotho-English Dictionary,* 8th revised and enlarged edition, Morija Sesuto Book Depot, Morija.

Meeussen, A.E. (1967) "Bantu Grammatical Reconstructions," *Africana Linguistica* III, 79-121.

Mutaka, M.N. (1991) "Vowel Harmony in Kinande," unpublished ms., University of Southern California [revised version of a 1986 ms. of the same title].

Odden, D. (1988) "Anti-antigemination and the OCP," *Linguistic Inquiry* 19, 451-75.

Odden, D. (1989) "Vowel Geometry," unpublished ms., Ohio State University

Odden, D. (1990) Kimatuumbi Phonology and Morphology, unpublished ms., Ohio State University.

Painter, C. (1967) "Cineradiographic Data on the Feature 'Covered' in Twi Vowel Harmony," *Phonetica* 28, 97-120.

Sagey, E. (1986) The Representation of Features and Relations in Non-linear Phonology, Ph.D. dissertation, MIT, published 1990 by Garland Publishing Co., N.Y.

Schane, S. (1984) "The Fundamentals of Particle Phonology," *Phonology Yearbook* 1, 129-55.

Stallcup, K.L. (1980) "A Brief Account of Nominal Prefixes and Vowel Harmony in Esimbi," in L. Bouquiaux, ed., *L'expansion bantoue*, vol. 2, S.E.L.A.F., Paris, 435-41.

Tucker, A.N. (1929) *The Comparative Phonetics of the Suto-Chuana Group of Bantu Languages*, Longmans, Green and Co., London; republished 1969 by Gregg International Publishers Ltd., Westmead, Farnborough, Hants.

Valinande, N. K. (1985) A Phonological Analysis of Kinande. Unpublished ms., Université Nationale du Zaire and Institut Pédagogique National (Kinshasa). [Consists of a portion of the author's 1984 Ph.D. dissertation "The Structure of Kinande," Georgetown University, Washington, D.C.]

Yip, M. (1988) "The Obligatory Contour Principle and Phonological Rules: a Loss of Identity," *Linguistic Inquiry* 19, 65-100.

Ziervogel, D., ed. (1967) *Handbook of the Speech Sounds and Sound Changes of the Bantu Languages of South Africa,* UNISA Handbook Series No. 3, University of South Africa, Pretoria.