VOWEL HARMONY IN NONLINEAR GENERATIVE PHONOLOGY:

AN AUTOSEGMENTAL MODEL

(1976 version)

by

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PREFACE

The following is a lightly edited version of a manuscript written between October 1975 and January 1976, and privately circulated among a few interested linguists at that time. It constitutes the preliminary version of a longer study of vowel harmony now in progress. While I am aware of its tentative nature, I have submitted it for wider circulation in the hope that it will become more readily accessible to readers who may wish to familiarize themselves with some of the original motivation for research into nonlinear phonology. An abbreviated presentation of the theory presented here appears in my article "The Autosegmental Treatment of Vowel Harmony" (Clements 1977).

The thesis of the present work is that the highly specific properties of vowel harmony offer motivation for a nonlinear mode of phonological representation. One such mode of representation has been proposed by Goldsmith for the treatment of tone and intonation (see Goldsmith 1976a,b and further references in Chapter 3). In the present study it is shown that a rather simple extension of this model provides the solution to certain problems that were not adequately dealt with by earlier, linear models of phonology. It is claimed, first, that an autosegmental theory of phonology must allow some segments to be treated as OPAQUE in the sense that they are lexically associated (i.e. bound by association lines) to features assigned to separate, related tiers of representation. This proposal, while extending the power of the theory somewhat, provides a natural treatment of certain otherwise problematical features of vowel harmony in Akan and Turkish. Secondly, it is proposed that the Well-formedness Condition must be supplemented with the notion of "Priority Clause" determining unique associations in cases where the Well-formedness Condition underdetermines the output. These proposals are presented in Chapter 3.

While I believe that the framework proposed here provides a fully adequate treatment of the topics covered in this study, it is nevertheless incomplete in the sense that it leaves open the important question of the treatment of neutral vowels in such languages as Finnish, Hungarian, and Mongolian. Thus it is evident that some elaboration of the present model is necessary. In this respect J.-R. Vergnaud has made the interesting proposal that certain classes of autosegmentally-represented features -- including vowel features -- are copied by a general convention into the phonetic matrices that they dominate on related tiers (Vergnaud 1977). This proposal allows neutral vowels to be treated as segments which are fully specified in underlying phonetic matrices. Somewhat different versions of this proposal are developed in a treatment of Mongolian vowel harmony by Chinchor (1978/9) and in unpublished work by Halle and Vergnaud (1978). I hope to return to this topic in the forthcoming study cited above.

My association with the Department of Linguistics at MIT as a Visiting Scientist in 1973-1975 provided a unique environment for the

exploration of new approaches to linguistic analysis. The present study grew out of the many opportunities I had for the exchange of ideas with members of the Department of Linguistics at that time. I would especially like to express my thanks to Morris Halle, whose contributions to my understanding of phonology are essential to whatever is worthwhile in the present proposals, and to John Goldsmith, whose suggestions and criticisms have provided invaluable encouragement in the preparation of this study, and whose pioneering work in autosegmental phonology has provided one of the most stimulating and significant advances in current linguistic research. I would further like to express my appreciation to Paul Kiparsky and Shosuke Haraguchi for many enlightening discussions and useful suggestions. Finally, I take this opportunity to thank Lloyd Anderson, Nancy Chinchor, Joseph Foster, John Jensen, David Leslie, Catherine Ringen, and Robert Vago for allowing me to consult unpublished manuscripts; I hope that the present study will justify their interest.

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The autonomy of various distinctive features clearly comes to light in the grammatical process known in certain languages under the name of *vowel harmony*.

R. Jakobson, G. Fant, and M. Halle
Preliminaries to Speech Analysis, 1952.

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CHAPTER 1

EARLIER PROSODIC MODELS

1. When we examine work on vowel harmony within a generative framework, i.e. one that presupposes an explicit set of rules relating underlying representations to surface representations, we find that most work to date has attempted to express constraints on vowel sequences in LINEAR terms.

Within such linear treatments, two principal approaches can be distinguished. The first approach, which I will term "linear prosodic" or simply "prosodic," attributes vowel harmony patterns to the presence of certain features of representation which are interpreted as SIMULTANEOUS with sequences of consonantal and vowel segments. In other words, while such features are linearly ordered with all other features of the same categorial status (e.g. phoneme-level features, morpheme-level features), their phonetic interpretation is carried out with respect to independently defined domains which may comprise more than one phoneme. Sections 2 and 3 of this chapter examine two versions of such an approach. The alternative to the "prosodic" approach, which I will term "segmental," is one which attributes no special status to vowel harmony at all. Vowel harmony is viewed rather as the effect of the operation of rules of the segmental phonology which determine vowel cooccurrence and patterns of vowel alternation, and which are allowed to have consequences for entire sequences of vowels occurring within independently-defined domains (usually, the word). In such a view, any phonological feature receives an interpretation only with respect to the segment (single-column matrix) to which it is assigned; features have phonetic consequences for other segments only by virtue of the operation of phonological rules of assimilation and the like. Segmental approaches to vowel harmony are examined in Chapter 2.

2. The two models to be examined in this chapter reflect the influence of the two most significant "prosodic" approaches to vowel harmony within the structuralist tradition: that of the Firthian School, as represented in such writings as Waterson (1956), Carnochan (1960), and Lyons (1962), and that of Z. S. Harris and his associates at the University of Pennsylvania (see especially Harris (1944) for a comprehensive statement).

The model proposed by T. M. Lightner in his article "On the Description of Vowel and Consonant Harmony" (1965) represents, in many respects, an attempt to translate the "prosodic" intuitions of Firthian phonology into the linear terms of standard generative phonology. While his treatment assumes most features of generative phonology as it was practiced at that time, he introduces three mechanisms that are specific to the treatment of vowel harmony. The first and most important of these is the notion of "root marker," the generative equivalent of the Firthian prosody of vowel harmony. "Root markers" are abstract features which are assigned to lexical roots along with their complement of semantic, syntactic, morphological, and phonological features. These markers are described as "abstract idiosyncratic propert[ies] of roots, analogous to the markers ANIMATE, TRANSITIVE, and others; the markers ANIMATE, TRANSITIVE have primarily syntactic reflexes, [root markers] primarily phonological reflexes" (Lightner 1965, 247-8). The second mechanism is a convention which distributes abstract root markers to each phonological segment of a word. In the version of this theory that appeared in Chomsky and Halle (1968), it was pointed out that this mechanism must in fact be treated as a language-particular rule, since the convention in question (Chomsky and Halle 1968, 374 (126)) distributes features to lexical items, which need not always correspond to fully-inflected words (Chomsky and Halle 1968, 377). Thirdly, Lightner assumed a subset of phonological rules that are defined, not on phonological features, but on root markers; these rules have the function of giving the root markers a phonological interpretation. These three mechanisms constitute, in effect, a single apparatus for the description of vowel harmony.

To account for "neutral" vowels, that is, vowels cooccurring with vowels of both harmonic sets, Lightner introduced rules which "corrected" any vowels incorrectly generated by his rules. His model was illustrated with examples drawn from Classical Mongolian. The two harmonic sets were characterized by the root markers +GRAVE and -GRAVE. A sample derivation follows, in which VH = vowel harmony, KH = velar harmony, and C = the correction rule ɨ → i:

(1) /cIlAGUn, +GRAVE/ → cIlAGUn (all segments marked +GRAVE)
→ cɨlaGun (by VH)
→ cɨlaγun (by KH)
→ cilaγun (by C)

It can be seen that at every stage, a phonological representation consists of a linearly ordered string of units. Thus, Lightner's devices have the effect of translating Firthian nonlinear representations into a set of linear representations.

This model is descriptively adequate to the treatment of vowel harmony systems which are completely regular, or which have neutral vowels. However once further irregularities are introduced into a system it proves inadequate. Such irregularities arise when the domain of a given harmony value is less that the word. One type of example was indicated by Kiparsky (1968). Finnish, as well as most other vowel harmony languages, has a large number of loan words which do not obey harmony constraints, for example *afääri* 'affair'. Nevertheless their affixes undergo harmony, harmonizing with the last (nonneutral) vowel of the stem: *afääri-ä*. In such cases harmony affects only the final vowel; however the distribution convention (or rule) distributes the root marker across all segments. Consequently the vowel harmony rule, which interprets the root marker, will assign an incorrect value to at least one of the stem vowels.[1]

A further and more troublesome source of irregularity is the fact that certain affixes in an otherwise regular harmony language may not alternate; these affixes retain their basic shape whatever the harmonic context. Let us consider an example from Kalenjin, a Southern Nilotic language spoken in Kenya which has a system of vowel harmony based upon the feature "tongue root advancing" (see Hall et al., 1974, for discussion). Most prefixes in this language alternate, showing agreement in harmonic category with the first vowel to their right (which may also be a prefix, or else a root vowel). Thus compare the variants of the two prefixes appearing with the roots par 'kill', ke:r 'see': kɪ-a-bar-ɪn, 'I killed you', ki-ɒ-ge:r-in 'I saw you' (the symbol [ɒ] here and throughout this study designates an unrounded half-open back vowel; see note 15, chapter 2). Certain prefixes, including the negative prefix ma-, fail to alternate; thus, with the root (i)un 'wash', we find ma-ti-un-gɛ: (here, it will be noticed, the suffix gɛ: is also invariant), rather than *mɒ-ti-un-gɛ:. The problem for Lightner's approach arises when a further, alternating prefix precedes the invariant prefix; in this case, the alternating prefix agrees in harmonic category, not with the stem, but with the invariant prefix: ka-ma-ɒ-gɛ:ṛ-ɒk 'I didn't see you' (247). The problem for the root marker theory, in examples of this type (which are quite common), is that there are two harmonic domains, but only a single root.

A further criticism offered by Kiparsky, stemming from observations by Bach, concerned the abstract nature of the root marker. The root marker, as Lightner conceived of it, has no universal interpretation within linguistic theory as do most other features. Nor, it might be added, does it act as a rule feature as do markers of morphological class; it does not identify an idiosyncratic class of forms that undergoes a particular rule, but determines the way a rule (vowel harmony) applies to a form. The introduction of root markers thus increases the abstractness of phonological theory to an undesirable extent.

There is an obvious way in which Lightner could have averted this criticism. Since root markers exist for the sole purpose of becoming converted into phonological features, why not use phonological features as root markers in the first place? If we chose this approach we could eliminate BOTH the objectionable use of abstract features AND the need for a rule (vowel harmony) converting the abstract features into phonological features; the descriptive apparatus required for vowel harmony would require only a single mechanism, the rule distributing features assigned to morphemes across all segments within the word. Clearly, the only factor preventing Lightner from adopting this solution was his assumption of linearity: it would have required a level of representation in which phonological features are assigned to domains of more than one segment.

The defects of Lightner's model can be summarized as (1) its assumption of linearity, forcing him to adopt an unnecessarily complex, abstract apparatus, and (2) its failure to express the fact that vowel harmony may apply to domains less than the word, as seen in the examples discussed above. Let us now turn to a somewhat more highly articulated prosodic model, which overcomes these objections in part.

3. The theory of prosodic description to which we now turn owes its inspiration to the notion of "supralinear" or "suprasegmental" phoneme developed by Harris and Welmers in a series of studies in the early and

mid 1940's (Harris 1942, Welmers and Harris 1942, Welmers 1946). This notion is used to characterize vowel harmony in the Fante dialect of Akan in the following way:

> Since all the vowel phonemes within the limits defined in 1.26 belong either to the tense or the relaxed series of vowels, (...) it may be desirable to indicate this characteristic limitation of vowel sequence ("vowel harmony") in some way. (...) We suggest the mark /'/, which then becomes a supralinear phoneme, like nasalization, to indicate that all the vowels within the defined limits are produced with the tongue relaxed rather than tensed. (Welmers and Harris 1942, 331)

This phoneme, like the analogous phoneme /'/ used to characterize emphasis in Morrocan Arabic (Harris 1942, where the proposal is attributed to Charles Ferguson), is linearly ordered with respect to all linear phonemes and junctures, but is interpreted, as indicated above, within a specified domain potentially encompassing several phonemes. "Supralinear" or "suprasegmental" phonemes are in effect single phonetic features, each of which is associated with a specific articulatory correlate. This approach does not suffer from the excessive abstractness of Lightner's model. The Harris/Welmers treatment has been incorporated into several later descriptions, most notably Williamson in her treatment of nasalization in Ịjọ (1963) and Stewart in his description of the Asante dialect of Akan (1967).

It can be appreciated, even before we examine this model in any detail, that the choice of where to place the suprasegmental phoneme ("prosodeme" for Williamson, "prosodic feature" for Stewart) within the linear string of phonemes represents a potential problem. No comparable problem arose in the case of Lightner's model since the "root marker" was (as a morpheme-level feature) coextensive with the root. Welmers and Harris discuss this problem in passing (331-2). As Stewart pays particular attention to the problem, we will consider his treatment of Akan (Asante) in some detail. Before doing so, however, we will review the relevant features of the Asante vowel system.[2]

On the surface level, Akan vowels can be classified into sets, +H and -H, on the basis of their alternations in certain environments, to be examined below:

(2)	+H	-H
	i	ɪ
	e	ɛ
	ɜ	a
	u	ʊ
	o	ɔ

The vowels a, ɜ will be termed "low vowels."

In describing the word-level distribution of these vowels (only the Asante dialect will be considered unless otherwise noted), it is simpler to deal first with the low vowels, and then with sequences of nonlow vowels. As Stewart pointed out (1967, 187), the choice between a and ɜ is wholly determined by context. The variant ɜ occurs if it immediately precedes a root beginning with the sequence "palatalized consonant followed by a", symbolized C^ya; or if it precedes a nonlow vowel of the +H series. Otherwise, we find the variant a. For example:[3]

(3) a. ɜ before a C^ya root:

wɜ-s^{y}ãnɪ	'he has come down'

b. ɜ before i, u, e, o:

kɜri	'weigh'
wɜ-bisa	'he has asked'
ɜko	'parrot'
pɪrɜko	'pig'

c. a elsewhere:

sãnɪ	'untie'
wa-sãnɪ	'he has untied it'
wa-g^{y}i	'he has taken it'
wa-kɜri	'he has weighed it'
wa-bɛ-tʊʔ	'it has come and laid'
sika	'money'

As for sequences of nonlow vowels (I use the term 'sequence' always in the sense 'maximum sequence', and regardless of whether the vowels are separated by consonants, or contiguous), let us examine their distribution first within roots, and then within root-affix complexes. Within a lexical root, all nonlow vowel sequences are +H or -H: k^{y}ɪrɛ 'show', tie 'listen', kotog^{wy}e 'knee'. This is true even when the nonlow vowel sequence cooccurs in the root with a low vowel: pɜtiri 'slip'.

A (nonlow) suffix vowel belongs to the same set as the final root vowel: ɔ-bɛ-jɛ-ɪ 'he came and did it', o-be-je-i 'he came and removed it' ɛ-bʊ-ɔ 'price', e-bu-o 'breach'; cf. in particular o-bisa-ɪ 'he asked', in which the two root vowels belong to different sets. In all these examples, the first morpheme is a prefix, the second the root, and the third the suffix.

Nonlow vowel sequences in prefixes always precede the root immediately, due to the fact that nonlow prefix vowels have low variants before a low prefix vowel (see Schachter and Fromkin 1968, 131). Such sequences are +H if the root is of the form C^ya... or if the first root vowel is nonlow and +H; otherwise they are -H: o-ko-gʷʸarɪ? 'he goes and washes', wu-be-num? 'you will suck it', but ɔ-bɛ-gʸɪ 'he will drink it', mɪ-kɔ-kɜri 'I go and weigh it', wʊ-bɛ-nʊm? 'you will drink it'. In all these examples, the final morpheme is the root.

We can summarize the distribution of nonlow vowel sequences in complexes in the following way: a nonlow vowel sequence is +H if it either contains a +H root vowel, or precedes a C^ya sequence; otherwise, it is -H. This statement is illustrated by the following examples; nonlow vowel sequences are underlined, and roots are enclosed in brackets:

(4)

+H sequences	-H sequences
[tie]	[kʸɪrɛ]
[pɜtiri]	wa-bɛ-[tʊ?]
o-be-[ji]-i	ɔ-bɛ-[jɛ]-ɪ
o-ko-[gʷʸarɪ?]	ɔ-bɛ-[gʸɪ]
wu-be-[num?]	wʊ-bɛ-[nʊm?]
o-[bisa]-ɪ	mɪ-kɔ-[kɜri]

Finally, within a verbal root in Asante (but not in other dialects), every +H sequence must contain at least one high vowel *i* or *u*. Consequently, a verbal root containing no high vowel must be -H.

We have attempted to summarize the distribution of vowels at the word level in Asante in terms of three statements, one dealing with the choice between variants of the low vowel, another dealing with sequences of nonlow vowels, and a third dealing with restrictions on vowels within verb roots. Let us now turn to the problem of formalizing these statements.

Stewart proposes to treat the distribution of Asante vowels in terms of the "prosodic feature" H, which is entered in linear phonological representations under certain conditions. This feature is identified as tongue root advancing, and thus is not to be equated with an abstract "root marker" as proposed by Lightner. Vowels are specified as [-H] in underlying ("hypophonological" or "deep") representation. Thus, Asante has only the five underlying vowels /ɪ, ʊ, ɛ, ɔ, a/. When the feature H is present in a root or word, it establishes a domain or "span" of harmony across strings of neighboring segments. The extent of this domain is defined by occurrences of the low vowel /a/, which bounds domains, with the provision that an occurrence of /a/ on the left of a domain forms part of that domain, while an occurrence of /a/ to the right does not. Otherwise, harmony domains do not contain low vowels. This characterization of "H-domains" can be summarized by the following formula, in which X, Y, Z, and W are variables:

(5) $\# \ (X \ \underline{a) \ Y \ H \ Z} \ (a \ W) \ \#$

where Y, Z do not contain # or a.

Any vowel occurring in a string corresponding to the underlined portion of the formula is assigned the feature "advanced tongue root".

Although H is linearly ordered with respect to the segmental phonemes, it is not placed at the left of its domain, as is frequently the practice in traditional Firthian prosodic analysis (compare, for instance, the treatment of a similar harmony system in Carnochan 1960). Rather, it occurs medially or finally, depending on certain conditions. In a verbal root, it occurs to the right of the rightmost high vowel, if one is present; otherwise it occurs to the left of a palatalized consonant followed by *a*. No other position is possible. In other roots, it is placed to the right of the rightmost nonlow vowel. These restrictions may be summarized as the following disjunctive well-formedness condition on lexical entries:[4]

(6) H in a verb root meets one of the following conditions:

(a) $Y \begin{bmatrix} +\text{syl} \\ +\text{high} \end{bmatrix} H \ Z$ and Z does not contain $\begin{bmatrix} +\text{syl} \\ +\text{high} \end{bmatrix}$, or

(b) $Y \ H \ C^{y} \ a \ Z$

H in other lexical roots meets the following condition:

$Y \begin{bmatrix} +\text{syl} \\ -\text{low} \end{bmatrix} H \ Z$ and Z does not contain $\begin{bmatrix} +\text{syl} \\ -\text{low} \end{bmatrix}$

The conditions of (6) are met by the following representations:

(7) # mɪtɪHɛ # → [mitie] 'I listen'

ɔsʊHrɔ # → [osuro] 'he is afraid'

ɔɔbɛHg^{wy}arɪʔ # → [oobeg^{wy}arɪʔ] 'he is going to wash'

kɔtɔg^{wy}ɛH # → [kotog^{wy}e] 'knee'

To summarize, Stewart's theory of harmony in Akan assumes only five underlying vowels, all marked -H, i.e. non-root-advanced. The feature (+)H is assigned to certain roots according to the conditions outlined in (6). The theory defines the DOMAIN of H independently and assumes an algorithm for assigning this feature to each vowel occurring within the domain. It can easily be seen that this theory provides a correct description of Akan harmony, in spite of the fact that this system is considerably more complex than that of most familiar harmony languages. It would furthermore be a simple matter to extend this theory to languages such as Classical Mongolian, as described by Lightner, while Lightner's approach is incapable of treating Akan correctly, due to its incapacity to deal with multiple harmony domains in words containing only one root.

A further interesting aspect of this theory is that it accomplishes three descriptive tasks at the same time: it accounts for the distribution of the variants of the low vowel, it accounts for the harmonic class of nonlow vowel sequences, and it accounts for restrictions on vowels within verb roots: in other words, it provides a complete formalization of all the statements given earlier. As a descriptive statement, therefore, it reaches a high level of generality. But we must still inquire whether it provides, in fact, the best explanation of vowel harmony in Akan.[5]

The low vowel has a distinctly anomalous status in Akan, and we might consider whether it in fact participates in vowel harmony alternations. We observe, for instance that this is the only segment that must be mentioned in the definition of the harmony domain (5), and it must be mentioned three times. Another unexplained aspect of this analysis is the asymmetry of the low vowel: it can be included in a harmony domain if it occurs to the left, but not if it occurs to the right. No other vowel exhibits this asymmetry.

Let us consider the possibility that the low vowel does not undergo harmony, but is an exception to it.[6] If this view is correct, then the leftmost low vowel in formula (5) should not be included in the domain of harmony. There is a fairly good reason for thinking that this must be the case. In Akan, we observe that lexical roots are invariant under harmony, never changing their phonological shape, while the affixes have two shapes, depending on the category of the root to which they are attached. For this reason it can be said that the root controls harmony in Akan. In languages of this type elsewhere, we observe a fairly general principle in operation which determines the value of any particular suffix. By this principle, harmony appears to "travel" outward from the root in a wave-like pattern, in such a way that the rightmost vowel of a root controls the value of suffixes, and the left-most vowel of a root controls the value of prefixes. The wave-like aspect of this principle is particularly in evidence when we observe the behavior of affixes which have invariant shapes: an invariant suffix will control the harmony of the suffixes to its right, while an invariant prefix will control the behavior of prefixes to its left. We have, in fact, already seen two instances of this principle. It was noted that in Finnish, it is the rightmost nonneutral vowel of nonharmonic loan words that controls the value of a suffix, rather than the leftmost: *afääri* 'affair', *afääri-ä*. In Kalenjin, we observed a case in which an invariant prefix controls the value of the prefix to its left: ka-ma-ɒ-ge:r-ɒk 'I didn't see you' (where ge:r is the root, and ma- the invariant prefix). For a further instance, this time involving an invariant suffix, we might turn to an example from Turkish discussed in this context by Vago. In Turkish, suffix vowels harmonize with the preceding vowel in backness, and high suffix vowels harmonize in rounding as well. Thus, the harmonizing personal suffix *-Im* is unrounded in *gel-ir-im* 'I come', *gül-er-im* 'I laugh', but rounded in *dur-ur-um* 'I stand'. The progressive suffix */Iyor/* is exceptional in that its second vowel does not alternate; it is always the nonhigh, rounded vowel *o*: *gel* 'come', *gel-iyor* 'is coming', *aç* 'open', *aç-ɨyor* 'is opening'. The personal suffix *-Im* may follow the progressive suffix, in which case it harmonizes with its final, nonalternating vowel: *gel-iyor-um* 'I am coming', *aç-ɨyor-um* 'I am opening' (Vago 1973, 595).

The principle which we observe operating in these examples can be formulated in the following way. Given a feature F which serves as the basis for harmony in a given language, a vowel in an alternating prefix will agree in value with the first instance of F to its right, while a vowel in an alternating suffix will agree with the first instance of F to its left. We shall see further instances of this widely valid principle as the discussion proceeds, and we shall see that certain apparent exceptions are not exceptions in fact.

Returning to Stewart's formulation of the domain of harmony (4), we can see that if a low vowel lying to the left of a domain governed by H is included in that domain, then the principle described above cannot be valid for Akan. This conclusion follows from the examination of examples such as wʊ-bɛ-pɔtiri 'you will slip', in which pɔtiri, it will be recalled, is the root. Under Stewart's hypothesis, the initial low vowel in this root harmonizes with the vowels to its right, and therefore acquires the value +H as the result of harmony. If this is true, however, then it cannot be true that the prefix vowels are controlled by the leftmost root vowel. Rather these vowels, which harmonize elsewhere (cf. wu-be-numʔ, wʊ-bɛ-nʊmʔ) fail to harmonize with the root vowel to their right just in case this vowel is low. Akan must therefore be an exception to the "wave" principle which characterizes harmony systems typologically similar to that of Akan.

A more likely explanation for the asymmetric behavior of the low vowel is that it is simply exceptional to harmony: it bounds harmony domains without participating in them. In this sense root-advancing harmony in Akan would be an example of a PARTIAL harmony system (much like rounding harmony in Turkish), in the sense that harmony applies to a subset of the vowel inventory only.

Further reason to believe that this explanation may be correct comes from the examination of a rule of the phrase-level phonology, mentioned by Stewart (1967, 190), but treated more fully by Schachter and Fromkin (1968, 56-7, 99-100), from whom I draw my examples. This rule changes a word-final -H vowel to +H if the first vowel of the next word is +H and belongs to the root, or (in the case of Asante) if the next word begins with the root sequence C^ya. Unlike harmony, this rule affects only a single vowel, and operates leftward only, rather than bidirectionally. Some examples follow (I have modified Schachter and Fromkin's transcription slightly to agree with the above examples):

(8)a. kum asɪ ji → kum asi ji 'kill this father-in-law' (As)
kill father-in-law this

b. oba fi → obɜ fi 'a child leaves' (As, Ak)
child leave

c. kwaamɪ fiti nɪ nsa → kwaami fiti nɪ nsa 'Kwame pricks his hand' (Ak)
prick his hand

d. kwaamɪ gʸam? → kwaami gʸam? 'Kwame condoles' (As)
condole

However, if the following root vowel is low (and not, in Asante, preceded by C^{y}), the metaphony does not take place:

(9) kwaamɪ kɜri 'Kwame weighs (it)' (*kwaami kɜri) (Ak)
weigh

We can explain the failure of metaphony to take place here in one of two ways. We could continue to maintain that the low vowel is subject to harmony, in which case the initial vowel of kɜri is +H. Then, in order to account for the fact that the metaphony rule does not apply, we could mark low vowels as exceptionally not providing a context for metaphony. Under this analysis, the low vowel would be exceptional in regard to two processes: it fails to condition vowel harmony in prefixes (wʊ-bɛ-pɜtiri), and it fails to condition metaphony in a preceding word (kwaamɪ kɜri). Alternatively, we could take the position that low vowels do not undergo harmony, and explain both of these apparent anomalies at once.

The rule of metaphony will have some such form as the following:[7]

(10) $$V \rightarrow [+H] \; / \; \underline{\quad} \; \# \left\{ \begin{array}{l} C^{y}a \\ C_0[+H] \end{array} \right\}$$

In this form, assuming the low vowel not to undergo harmony, Metaphony will apply to (8a-d) but not to (9). But we can now see that this rule will also account for the distribution of the variants of the low vowel, provided we parenthesize the word boundary; it will apply to all the underlying low vowels in (3a-b) but to none of those in (3c) (with the exception, of course, of the second low vowel of wa-kɜri). A slight generalization of (10), therefore, fully accounts for all the observed variants of the low vowel.[8] Consequently there is no longer any motivation for including the low vowel in the domain of vowel harmony itself.

We have been examining the Akan vowel system in order to determine the appropriate set of statements to be provided by a proposed descriptive model. It now seems clear that if the model is to give an accurate picture of the vowel harmony system, it must exclude low vowels from the domain of the prosodic feature H. This can easily be done; (5) can be revised as follows:

(11) $\#\ (X\ a)\ \underline{Y\ \ H\ \ Z}\ \ (a\ W)\ \#$

where Y, Z do not contain # or a

However, the revised formulation still leaves open the question of why the vowel a must be mentioned three times. We should prefer to treat the various statements involving a as a SINGLE condition, reflecting the exceptional status of a within the harmony system. This is because these statements serve the single purpose of preventing the feature H from being assigned to low vowels. Somehow, then, a should be characterized once and for all as exceptional to harmony. (It would not be sufficient simply to assign it an exception feature, since we also want occurrences of a to block the spread of H to elements within the variables X and W.)

A further problematic aspect of this theory derives from its assumption of linearity. Let us return to the well-formedness condition on the distribution of H in lexical entries, stated as (6) above. In verb roots, the prosodic feature H may only occur to the right of the rightmost high vowel, if one is present, or otherwise to the left of a palatalized consonant followed by a. The first condition is a way of stating the restriction that verb roots only bear the feature H if they have at least one high vowel. (It may be noted that this restriction is difficult to state within the traditional theory of morpheme structure conditions, due to the need for a quantifier.)

Why, however, is the feature H restricted to the right of the RIGHTMOST high vowel, rather than (for instance) the LEFTMOST? This decision is clearly an arbitrary one, since the exact location of H within the domain it controls has no consequences for the way H is distributed across vowels. Also, why need it be restricted to the RIGHT, rather than the LEFT, of such a vowel? Again, this decision is arbitrary; but a decision of some sort, however arbitrary, is forced upon us by the assumption that phonological representation is linear. We should prefer to have a means of formulating the restrictions upon H in a way that does not require H to be ordered with respect to "nonprosodic" segments, but which at the same time expresses the association between H and relevant aspects of a representation.

The lexical condition (6) can be revised in a way that does not require arbitrary assumptions about ordering, however, if we suspend the assumption of linearity. Let us represent a relation "association" holding between a segment and a prosodic feature by writing the feature directly above (or below) the segment with which it is associated. The symbol H can be used to represent "advanced tongue root" and the symbol $\bar{H}$ to represent "nonadvanced tongue root". (6) can now be replaced by:

(12) a. H in a verb root meets one of the following conditions:

$$\overset{H}{\begin{bmatrix}+\text{syl}\\+\text{high}\end{bmatrix}} \qquad \text{or} \qquad \overset{H}{C^{y}a}$$

b. $(\overline{H})$ in other lexical roots meets the following condition:

$$\overset{(\overline{H})}{[+\text{syl}]}$$

Each entry in (12) is to be understood as a conditional of the form: the top line implies the bottom line. Thus, the condition reads: in verb stems, H can only be written over (i.e. associated with) either a high vowel, or a palatalized consonant which is followed by a; in other entries, the only condition is that H (or $\overline{H}$) must be written over a vowel. It is no longer necessary to say that this vowel must be nonlow if H is chosen, since we can further assume a redundancy condition to the effect that all low vowels are associated with the feature $\overline{H}$, that is:

(13) $$\underset{\overline{H}}{\begin{bmatrix}+\text{syl}\\+\text{low}\end{bmatrix}}$$

As a consequence of (13), the configuration of (12b), with H as the prosodic feature, can only be met by nonlow vowels.

For the moment let us suspend judgement on another redundancy condition suggested by Stewart, that all prefixes and suffixes are redundantly non-root-advanced; in the framework we are advancing, this would be equivalent to saying that all affixes are redundantly associated with $\overline{H}$.

The theory developed so far gives us lexical entries of the following form:

(14) tie 'listen' : $t\,\overset{H}{i}\,e$ OR $t\,i\,\overset{H}{e}$ OR $t\,\overset{H}{i}\,\overset{H}{e}$

bisa 'ask' : $b\,\overset{H}{i}\,s\,\overset{\overline{H}}{a}$

g^{wy}arɪʔ 'wash' : $\overset{H}{g^{wy}}\,\overset{\overline{H}}{a}\,r\,\text{ɪ}\,\text{ʔ}$

Now let us inquire into the manner in which the feature H extends itself over the domain of the word. According to (11), H spreads until it reaches either a low vowel, or the end of the word. We now observe that it is not necessary to introduce some feature marking the low vowel as exceptional to harmony, since it already has a mark that serves that purpose, the redundantly associated feature $\overline{H}$. Assuming that all occurrences of H and $\overline{H}$ are aligned on a single "path", we can say that these features extend their domain leftward and rightward until they reach either another occurrence of H or $\overline{H}$, or else the end of the word.

This proposal will not yet account for prefix and suffix harmony if we maintain the assumption that affixes are redundantly associated with the feature $\overline{H}$. But this assumption proves to be unnecessary, and can be dropped. The process of domain extension can be intuitively characterized as follows, where arrows indicate the direction of extension:

$\longleftarrow H \longrightarrow$
(15) a. e - bu - o   e - bu - o   'breach'

$\longleftarrow\!\!\!-\!\!\!-\!\!\!-\!\!\!- \overline{H} \longrightarrow$
b. o - be - je - i   ɔ - bɛ - jɛ - ɪ   'he came and did it'

$\longleftarrow H\ \overline{H} \longrightarrow$
c. o - bisa - i   o - bisa - ɪ   'he asked'

Notice in particular that H in (15c) cannot extend its domain rightward, since its path is blocked by $\overline{H}$; and similarly $\overline{H}$ cannot extend its domain leftward. What we have arrived at is a first approximation of a theory of nonlinear phonology in which such concepts as "association," "domain" and "extension" remain to be formalized. We return to an interpretation of these concepts within an explicit theory in Chapter 3.

We have seen, then, that a simple modification of Stewart's model, permitting prosodic features to be represented on independent lines of representation, overcomes the arbitrariness imposed by the assumption of linearity. The resulting model can be seen to converge in important respects with that of Lightner: the supralinear prosodic feature plays the same role as does Lightner's root marker, except that the root marker has here been replaced by a phonetic feature; the process of domain extension corresponds to the rule distributing the root marker across segments within the word.

4. The prosodic models discussed above have shared two assumptions: (1) that certain features of phonological representations may have phonetic consequences for domains larger than the segment; (2) that phonological representations are linear. These models have led, as we have seen, to certain problems. It has consequently been widely thought that the first assumption was mistaken, and that phonological representation is strictly linear in the sense that phonological features strictly characterize only the segments which contain them as entries in their feature matrix.

I have attempted to show here that the shortcomings of the two prosodic models examined in this chapter can be traced, not to the first assumption (that of prosodicity), but to the second (that of linearity). In the next chapter, some of the properties of models which view vowel harmony as nonprosodic in nature - i.e., models which reject assumption (1) and accept assumption (2) - will be examined. It will be argued that these models suffer from serious limitations, in their turn.

NOTES TO CHAPTER 1

[1] It would be possible to mark such roots [-Vowel Harmony]. However, such an approach would fail to account for the fact that the suffix always agrees in category with the final root vowel.

[2] See Stewart (1967), Berry (1957), and Schachter and Fromkin (1968). Akan is a Volta-Comoe language of the Niger-Kordofanian family, spoken in Ghana. The earlier designation "Twi" is still occasionally used by some writers. Examples are from the Asante (As) and Akuapem (Ak) dialects; tone is not indicated. The vowel transcribed as **3** is phonetically variable from dialect to dialect, with a range of values including at least [æ (As), ɛ (Ak), e (Fante)]. For this reason the term "low vowel" is used to refer to the set a,**3** , although strictly speaking this characterization is phonetically accurate only for Asante.

I have retranscribed Stewart's digraphs Cw and Cy (indicating rounded and palatalized consonants, respectively) as C^w and C^y, and his trigraph Cwy as C^{wy}, in order to avoid any confusion concerning their monophonematic status. [j] represents the palatal glide.

[3] The following description modifies Stewart's 1967 formulation in one detail. Stewart originally stated that "a occurs to the exclusion of **3** before ɛ, ɔ, e, o" (1967, 187). However, this formulation only concerned the verbal system; in nouns only 3 occurs before e, o as the examples of (3b) show. As for verbs, Stewart (1969) records the variant Asante forms w**3**-be-ji, wa-be-ji 'he has come and removed it', remarking that the latter form "is probably less common"; V. Fromkin regards it as marginal (personal communication). Finally, in Akuapem, it is clear that **3** occurs to the exclusion of a before e, o: Stewart gives the forms w**3**-g^ye 'he has taken it', **3**-g^{wy}o 'it has cooled' (Stewart 1967, 189).

[4] It must be kept in mind that this formulation is a slight modification of Stewart's, in accordance with the remarks in note (3), above. As will be recalled, it applies only to the Asante dialect.

[5] An alternative generative theory of Akan vowel harmony is presented in Schachter and Fromkin (1968). While in other respects these writers accept the framework of Chomsky and Halle (1968), they depart from that framework in their treatment of vowel harmony, adopting an approach very similar to that presented in Kiparsky (1968). Vowel harmony is stated in terms of a morpheme structure condition (55) and a phonological rule involving variables (98). Their morpheme structure condition states that all vowels in a morpheme agree in terms of "tenseness" (Stewart's "tongue root advancing"). Accordingly, the underlying representation of bisa 'ask' is /bisə/, and the underlying representation of kari is /kəri/, where /ə/ is the tense counterpart of /a/. In order to account for the fact that affixes abutting on /ə/ are non-tense, e.g. o-bisa-ɪ, mɪ-kɔ-k**3**ri, the rule of vowel harmony is conditioned to apply only when the determinant vowel is nonlow. Finally, in order to account for the phonetically

different quality of the low vowel in bisa [bisə] and kari [kɜri], they introduce a rule fronting ə to ɜ before a (nonlow) tense vowel (101).

In the following discussion I will argue that only one low vowel, /a/, appears in underlying representations, and that this vowel does not undergo harmony. I am therefore forced to disagree with Schachter and Fromkin's analysis; phonological reasons for my disagreement are given below. The only argument offered in favor of an underlying low tense vowel in the varieties of Akan discussed by Schachter and Fromkin consists of forms such as [o-ko-djəmʔ] (Schachter and Fromkin 1968, 97). In such forms, the prefix vowels are argued to be tensed as a result of the presence of a nonlow tense vowel in the root at an earlier stage of derivation (this vowel is later deleted). The presence of this nonlow tense vowel is held to imply that the low vowel is tense, due to the morpheme structure condition that all root vowels agree in tenseness. However, this analysis cannot account for forms such as ọ-ko-g^{wy}arɪʔ 'he goes and washes', mi-s^{y}ãnɪ 'I come down', in which the nontense vowel ɪ attests to the nontense nature of a.

[6] This reanalysis was first suggested to me by Morris Halle.

[7] The fact that we find the same disjunction of environments for vowel harmony and for metaphony strongly suggests that these environments share a feature in common. In fact most accounts have assumed (though never conclusively demonstrated) that the feature +H (advanced tongue root, tense, etc.) occurs somewhere, or at some point, in the representation of roots of the form C^{y}a. Stewart at first suggested that these roots all had a high +H vowel historically (Stewart 1967, 200), although he has recently informed me that he no longer holds this view.

[8] As Stewart (1971) and others have pointed out, a low vowel produced with an advanced tongue root would be highly marked both in articulatory and acoustic terms, and in fact proves to be rare, in vowel systems showing root-advancing harmony. As was pointed out earlier (note 2), this vowel is unstable in Akan, showing several variants from dialect to dialect. It would appear unnecessary to place a special condition on the Metaphony rule to account for each of these variants; rather, late rules idiosyncratic to each dialect can account for the correct phonetic realization of the +H low vowel created by Metaphony.

CHAPTER 2

EARLIER NONPROSODIC MODELS

The prime descriptive problem posed by vowel harmony is that of determining the principle according to which harmony domains are governed. In this chapter an informal characterization of this principle, termed the principle of ROOT CONTROL, is offered (section 3). Two nonprosodic approaches to vowel harmony are examined, and it is shown that neither is capable of incorporating this principle in a natural way.

1. In many, or probably most, harmony languages, we find that some vowels fail to alternate under the conditions for harmony; they appear in a single, invariant form. Such nonalternating vowels may be of two types. NEUTRAL vowels do not affect the harmonic category of neighboring vowels. This can be determined from the fact that occurrences of a neutral vowel internally in a word do not break the word into two harmonic domains; vowels to the left of the neutral vowel must agree with vowels to the right. In Finnish, for example, *i* is neutral; it is therefore compatible with both front and back vowel words, for example: *korist-a-va-nsa*, *ylist-ä-vä-nsä* (Kiparsky 1968).

In contrast, OPAQUE vowels affect the harmonic category of neighboring vowels. Thus occurrences of opaque vowels internally in a word regularly divide the word into two harmonic domains, which do not necessarily agree in harmonic category. In Akan, *a* is opaque; therefore vowel sequences to the left of *a* need not agree with sequences to the right: o-bisa-ɪ, o-ko-g^{wy}arɪ?.

A vowel which is normally not opaque may be opaque in certain contexts, for instance in certain morphemes. Thus, in Kalenjin, *a* is an opaque vowel in the negative prefix ma- of ka-ma-ɒ-geːr-ɒk, but not in the personal prefix a- of kɪ-a-bar-ɪn, since it alternates with ɒ in ki-ɑ-geːr-ɪn.

Neutral vowels and opaque vowels are superficially similar, due to the fact that both may cooccur freely with vowels of either harmonic category. However the difference between them is fundamental: neutral vowels always function "as if" they belonged to the harmonic category of their neighbors, while opaque vowels always function as members of a single category.

With these distinctions in mind, let us try to formulate a hypothesis concerning harmony domains, first in roots, then in affixes. Nonexceptional roots in a harmony language appear to conform to the following principle:

(1) maximal strings of root vowels V* containing no opaque vowels agree in harmonic category.

examples (Akan): kotogʷʸe V*   pɜtiri V*

(This principle is correctly stated, of course, only if neutral vowels do in fact agree in harmonic category with their neighbors at the relevant level of description. This question will be discussed further below.)

The hypothesis concerning the harmonic behavior of affixes, given earlier in Chapter 1, section 3, can now be given a slightly sharper formulation. Let us say that the feature(s) serving as the basis for harmony in a given language are the "harmony-characterizing features". Then:[1]

(2) maximal strings of nonopaque prefix (resp., suffix) vowels V* agree in harmonic category with the first occurrence of a harmony-characterizing feature to their right (resp., left). Examples:

(a) (Kalenjin) ki-ɒ-[ge:r]-in

(b) (Akan) o-[bisa]-ɪ

(c) (Finnish) [olympial]-i-ssa-han

(d) (Turkish) [gel]-iyor-um

(e) (Kalenjin) ka-ma-ɒ-[ge:r]-pk

The underlined portions are the strings V* of (2); roots are enclosed in brackets. In (a), both prefix vowels constitute a string V*, and the suffix vowel does as well. In (b), the prefix vowel and the suffix vowel constitute separate strings V*, and do not agree in harmonic category. In (c), the three suffix vowels, including the neutral vowel *i*, constitute V*. In (d), the vowel o is opaque, and is accordingly excluded from any string V*. However *i* constitutes a string V* agreeing with the value "unrounded" of the final root vowel, and *u* constitutes a string agreeing with the value "rounded" of the suffix vowel *o*. In (e), the situation is just the converse of that of Turkish. The prefix vowel ɒ agrees with the value [+ATR] of the first root vowel, while the vowel a of the prefix ka- agrees with the value [-ATR] of the opaque prefix vowel a of ma-.

In (1) and (2) above, strings of vowels (with possible intervening consonants) analyzed as V* constitute DOMAINS. (1) and (2), therefore, are hypotheses concerning the principles according to which vowels within domains of vowel harmony are governed.

These principles cannot be taken as characterizations of the surface phonetics of all harmony languages. They properly apply only to a somewhat more abstract level of phonological description. We shall try to determine what this level is as the discussion proceeds.

2. Let us examine certain proposals for the description of vowel harmony in segmental terms. The differences between the segmental and the prosodic approaches is not merely one of formal notation, but involves fundamentally different conceptions of the nature of vowel harmony. In particular, prosodic approaches typically view vowel harmony as involving a spreading or distension process, while segmental approaches regard it as involving assimilation of some vowels to other vowels.

We need not look far for the antecedents of what I am here terming "segmental" approaches to the description of vowel harmony in the structuralist tradition. In what one might term the mainstream American view, vowel harmony was viewed as a set of cooccurrence restrictions on vowel phonemes. Cf. Bloomfield: "Some languages have the peculiar restriction, known as VOWEL HARMONY, of tolerating only certain combinations of vowels in successive syllables of a word" (1933, 181). This approach is exemplified in such traditional descriptions as Poppe's (1954) treatment of Classical Mongolian. In such accounts, no "suprasegmental" or "prosodic" elements are set up in addition to the set of vowel phonemes.

2.1. In generative phonology, the segmental treatment of VH takes two directions. One, viewing assimilation as "acting at a distance", assumes that all changes defined on a string by a rule are carried out simultaneously. Another, viewing assimilation as affecting only neighboring segments, allows a rule to reapply to its own output. These approaches are generally known as the SIMULTANEOUS and the ITERATIVE theories of rule application.[2]

Let us illustrate these approaches - or rather particular, simplified versions of each one - with examples from Turkish.[3] Vowel harmony in Turkish can be regarded as consisting of two independent systems, one based on the back-front (velar-palatal) dimension, the other on lip rounding vs. its absence. Accordingly Turkish vowels can be classed for the purposes of vowel harmony into the following four sets:

	front	back
unrounded	*i*, *e*	*ɨ*, *a*
rounded	ü, ö	*u*, *o*

The symbols "I" and "E" are frequently used in citing suffix vowels in isolation, and in the underlying (or morphonemic) representation of Turkish words. "I" represents a high vowel with the variants (*i*, *u*, ü, *ɨ*), and "E" represents a nonhigh vowel with the variants (*e*, *o*, ö, *a*).

The system of backness harmony is relatively straightforward. All vowels in (harmonically regular) roots agree in backness; all nonopaque suffix vowels agree with the first specification for backness to their left: *ɨstanbul* 'Istanbul', *türkiye* 'Turkey', *adam-lar-a* 'to the men', *köprü-ler-e* 'to the bridges'. Opaque suffix vowels impose their category upon following suffix vowels: recall the example *gel-iyor-um* 'I am coming', in which the vowel *o* is invariant.

Further irregularities are introduced into the system by certain consonants. While their value is normally predictable in terms of the vowels of their immediate environment, there are a substantial number of exceptional cases. We shall look at these later in the discussion.

A segmental approach will regard opaque vowels (such as the *o* of *-Iyor*) as exceptions to vowel harmony, and will mark them with a diacritic if (as in this case) they are idiosyncratic. We shall assume, then, that the feature [-BH] forms part of the composition of the segment *o* in this morpheme.

(A) <u>a Simultaneous Application model.</u>

Let X, Y, Z be variables subject to negative conditions. Structural descriptions of the form A(B) are regarded as consisting of two cases, ordered as follows: AB, A. These cases are disjunctive in the sense that if the longer case applies to a segment, the shorter case does not. All vowels meeting the structural description of the rule undergo its structural change simultaneously. The backness harmony rule will be:

$$V \rightarrow [\alpha\text{back}] \;/\; [\alpha\text{back}]\; X \;\_\_\_\; Y \;(\; [-\text{BH}]\; Z \;)\; \#$$

where X, Y, Z, ___ do not contain #, [-BH]

(i) the string *adam-lar-a* is represented as: $a_1da_2m\text{-}lE_1r\text{-}E_2$ (the indices are for reference purposes only). As no vowel is marked [-BH], only the second (shorter) case of the rule is defined. It will be observed that for any given vowel, several analyses of X may be possible; for instance, if $V=E_2$, we can analyze X alternatively as $da_2m\text{-}lE_1r$ or $m\text{-}lE_1r$. By convention we stipulate that in such a case, only the longest interpretation is chosen. Thus the string is analyzed as follows:

<u>if V =</u>	<u>then X =</u>
a_2	d
E_1	da_2ml
E_2	$da_2m\text{-}lE_1r$

Thus for each vowel under analysis, the term [αback] of the

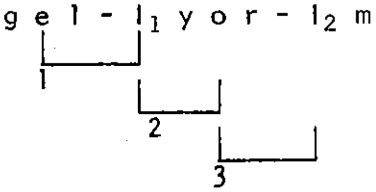
SD corresponds to the vowel a_1. Accordingly, all vowels are (simulataneously) assigned the value [-back]. (ii) the string *gel-iyor-um* is represented as follows: gel-I_1yor-I_2m. Since *o* bears the feature [-BH], the longer case is selected first. The unique interpretation of XVY is l-I_1y, and consequently the change $I_1 \rightarrow$ [-back] is defined. Due to the disjunctivity of the condition the shorter case applies only to the string to the right of *o*. The unique interpretation of XVY is now r-I_2m, and the change defined is $I_2 \rightarrow$ [+back].

(B) an Iterative Application model.

This model, in keeping with its hypothesis that assimilatory rules do not apply "at a distance", does not allow the use of variables ranging over elements of the same class as those that undergo the change. Thus, in the case of vowel harmony, it rejects the use of variables ranging over vowels. The rule may be stated:

$$V \rightarrow [\alpha\text{back}] \;/\; \underset{[\alpha\text{back}]}{V} \quad C_0 \;\underline{\quad}$$

It will be stipulated that the above rule applies from left to right across the word. The string is scanned, therefore, starting with the leftmost vowel, and proceeding rightward. For each successive pair of vowels scanned, the one on the right is assigned the value of the one on the left. Let us consider the example gel-I_1yor-I_2m. The rule scans successive portions of this string as follows:



When portion (1) is scanned, I_1 is assigned the value [-back], in agreement with *e*. No application is defined on portion (2), since *o* is marked [-BH]. When portion (3) is scanned, I_2 is assigned the value [+back] in accordance with the value of *o*.

(The application of the rule to *adam-lar-a* is straightforward.)

It should be stressed that the two models outlined above are only illustrative in nature; it is not claimed they represent the exact views of any particular writer.

Rounding harmony, while slightly more complex, does not present any particular difficulty to these models. In Turkish roots, nonhigh vowels can be round only initially (nonnative roots can be exceptions: *pilot*

'pilot'). In suffixes, nonhigh vowels are redundantly nonround (an exception is the second vowel of the progressive suffix *-Iyor*), and therefore opaque to rounding harmony. Consequently only high noninitial vowels in a word agree with the preceding vowel in rounding: *somun* 'loaf', *somun-um* 'my loaf', *somun-lar* 'loaves', *somun-lar-ɨm* 'my loaves'.

One or two remarks might be in order. First of all, the models I have given above are not free of problems, even given the slight range of data considered so far. One might question, for instance, the use of the feature [-BH] in the structural description of the simultaneous backness harmony rule. In effect, the rule is required to mention itself. This is, in fact, the general case: any vowel harmony rule, if it is to apply correctly, will have to insert a feature referring to itself in the appropriate part of the structural description, in order to insure that opaque affixes establish new harmony domains. Thus, the two subcases abbreviated by the parenthesis notation do not represent independent rules, as they do elsewhere in phonological description; each case implies the existence of the other.

The iterative model is embarrassed by the fact that the direction of application must be separately stated for each rule. While some writers have claimed that directionality is predictable from the form of the rule alone (Lightner 1972, Howard 1972), it has been shown that this claim must be significantly weakened (Jensen and Stong-Jensen 1973).

2.2. A critical problem for all segmental theories is that of expressing the relationship between root harmony and affix harmony. As a general rule, if a language has affix harmony of a certain type it has root harmony of the same type, although the converse is not necessarily true (cf. Yoruba). Furthermore, we generally find that both root harmony and affix harmony are subject to the same conditions; thus the set of vowels neutral to one system is neutral to the other. These facts suggest that root and affix harmony constitute a single phonological process. However, segmental descriptions have been forced to provide separate statements of vowel harmony in roots and in affixes, which cannot be formally related in the description.

One obstacle to the unified expression of root and affix harmony comes from the fact that certain roots - expecially nonnative roots - may violate the normal harmony constraints. In such cases, suffixes continue to show regular behavior, agreeing with the first nonneutral vowel to the left. In Turkish, the root *otobüs* 'bus' does not conform to backness harmony; but suffixes are front in accordance with the final root vowel: *otobüs-ler-de* 'on the buses'.

Words of this form pose a particular problem for a theory of simultaneous application, since such a theory must express the fact that a suffix vowel assimilates to the FINAL vowel of the root (rather than the initial vowel) just in case the root is exceptional to harmony. The iterative approach is not embarrassed by such examples since it may assume that all vowels in such roots are marked with an exception feature; thus in scanning a word such as *otobüs-ler-de* from left to right, no vowel undergoes the change until the first suffix is reached.

A further obstacle to the expression of root and affix harmony in a single generalization is due to the fact that vowels within roots may be subject to different coocurrence restrictions than elsewhere in words. In some cases, these conditions may be inconsistent with harmony constraints. In Akan, for instance, we have seen that within roots, harmony is observed only within sequences of nonlow vowels. In the word, however, we saw that the rightmost root vowel, whether low or nonlow, determines the value of the suffix, while the leftmost root vowel, whether low or nonlow, determines the value of the prefix: compare o-bisa-ɪ 'he asked', in which the root vowels disagree in harmonic category, with o-fiti-i 'he entered', in which they do not. The problem here is to devise a single rule that will account for the harmony in the latter example while not causing the root vowel *i* to assimilate to the following *a* in the former example. It would be inappropriate, here, to assign the feature [-vowel harmony] to the root bisa, since this root is perfectly regular in its structure. Harmony is defined only across maximal strings of nonlow vowels: compare pɜtiri 'slip', in which the two final vowels agree in harmonic category.

A second general problem raised by the segmental treatment of vowel harmony concerns the indeterminacy of the underlying form of vowels. In a theory attempting to describe root harmony by the same rule that describes affix harmony, which root vowel in, say, o-fiti-i do we choose as the determinant? In a language in which suffixes always agree with the (final) root vowel, how can we justify our assumption that a given suffix has this or that vowel in its underlying form?

Lightner was one of the first to recognize the indeterminacy problem, and viewed it as providing strong motivation for his prosodic treatment: "The interpretation of harmony as an assimilation process leads us to question which segment is to be considered basic - whether the first vowel of the root, whether the second vowel of the root, and so forth. In clear cases, such as the one presented by Classical Mongolian, the answer to this question will be arbitrary (. . .)" (Lightner 1965, 249).

In the case of alternating suffixes with no invariant allomorphs, no choice of underlying form on language-internal grounds is possible. One might then either take the agnostic position that suffixes are not lexically specified for the harmony feature at all, or else appeal to language-external arguments for a solution. One version of the latter position is that suffixes are fully specified and take the least marked value of the harmony category, as determined by universal marking conventions of the sort suggested in Chomsky and Halle (1968). This position is discussed and defended at some length in Kiparsky (1968).

3. In the preceding discussion I have assumed that the principles governing vowel harmony can and should be summarized in a single statement. However it is not yet clear what such a statement would be.

Let us try to extend and refine the notion of OPAQUE VOWEL introduced earlier. Opaque vowels were defined as vowels which never alternate, and function as members of a single harmonic category. Such vowels do not appear at random, but are defined either lexically (in the case, for instance, of the opaque vowels of certain suffixes, such as the invariantly back final vowel of Turkish *-Iyor*), or phonologically (in Akan, the opaque status of the low vowel *a* is a result of the segment structure condition specifying the low vowel as redundantly [-H]).

Let us extend this category to include another type of vowel whose harmonic status is determined by rule. In Turkish, roots are subject not only to the vowel harmony conditions on the coocurrence of back and rounded vowels, but also to a condition sometimes known as Labial Attraction. As Zimmer (1969) describes this principle, if within a morpheme the vowel *a* is followed in turn by a labial consonant (*p*, *b*, *f*, *v*, *m*) and a high vowel, the high vowel must be labial, that is *u*. Somewhat over sixty morphemes are found to conform to this condition; of the dozen or so exceptions, most are quite uncommon. For these reasons Zimmer concludes that the condition of Labial Attraction expresses a reasonably accurate generalization about words of common use in Turkish (Zimmer 1969, 311). Examples, which appear to be mostly bisyllabic, include *karpuz* 'watermelon', *čabuk* 'quick', *avuč* 'palm of hand', and *sabun* 'soap'; they include bases of both Turkish and foreign origin. This principle applies only at the level of the root, thus we find *av-ɨ* 'hunt' (acc.) rather than **av-u*. The roots themselves, while not conforming to roundness harmony, induce roundness harmony in suffixes: *tavuk-Im* → [*tavuǧ-um*] 'my chicken' (examples adapted from Foster 1968).

Thus in Turkish, high vowels are stipulated as round in the stated environment by a morpheme structure condition. Vowels of this type can also be considered OPAQUE; they do not alternate, and they function as a member of a single category only. In general, we can say that an opaque vowel is one whose harmonic category is GRAMMATICALLY STIPULATED, whether lexically or by phonological rule.

It will prove useful to provide a relational notion to supplement the relations "to the left of" and "to the right of" that we have used up to this point. Goldsmith, in unpublished work, has suggested an extended notion of left and right which is convenient for certain descriptive purposes. It will be said that an element A is NOT TO THE LEFT OF an element B if it is either unordered with respect to it, or to its right. Similarly, an element A is NOT TO THE RIGHT OF B if it is unordered with respect to it, or to its left. Furthermore, it is stipulated that an element A that is unordered with respect to another element B is CLOSER to B than an element to the left of B, or to the right of B.

Given these notions and the more general definition of opaque vowels, we can reformulate the restrictions on vowel harmony in roots (1) and in affixes (2), given above, in terms of the following principle of ROOT CONTROL:

(3) A domain containing maximal sequences of nonopaque vowels agrees with the closest occurrence of a harmony-characterizing feature F such that if the domain contains prefixes (resp., suffixes), F is not to its left (resp., right).

Notice that this statement covers four cases, as follows:

(a) the domain contains neither prefixes nor suffixes (that is, it consists of a root); in this case the domain agrees with the closest occurrence of F.

(b) the domain contains prefixes but not suffixes; in this case the domain agrees with the closest occurrence of F not to its left.

(c) the domain contains suffixes but not prefixes; in this case it agrees with the closest occurrence of F not to its right.

(d) the domain contains both suffixes and prefixes; in this case it agrees with the closest occurrence of F neither to its left nor to its right, that is, unordered with respect to it.

To see how these cases apply, let us examine some examples. (We shall continue to exclude nonnative or exceptional roots from this description. Below we shall consider a way of integrating them into it. It is further assumed, for the purposes of the discussion, that affixes are not underlyingly specified, and that no root vowel is opaque unless its value can be predicted from some rule of the grammar.)

Let us consider first some simple roots: domains (maximal sequences of nonopaque vowels) are underlined:

(a) (Akan) pɔtiri

(b) (Turkish) *karpuz*

In (a), the low vowel is opaque; hence the domain consists of the string *iri*. Regardless of whether we consider the feature [+H] to be located on one of the two vowels, or both of them, or to be coterminous with them, this feature will be the "closest", as this term was defined above. In (b), considering only the roundness harmony system, the vowel *u* is opaque as a result of labial attraction; however initial vowels in Turkish morphemes are subject to no conditions on roundness, hence *a* constitutes a domain. Whether we regard *a* as intrinsically specified for nonroundedness, or simply coterminous with this feature, it will be assigned this feature (vacuously, in the first case) by case (a).

Now let us consider the prefix case (3b); in the following examples, only the domain in question is underlined, and roots, as before, are bracketed:

(c) (Akan) wu-be-[num?]

(d) (Kalenjin) ma-ti-[un-]gɛ:

(e) (Akan) mɪ-kɔ[-kɜri]

In (c), as no vowels are opaque, all vowels form a single domain. Here, it is crucial that affixes not be underlyingly specified by any general principle; if they were, there would be no unique feature F which is "closest" to the domain. Assuming, then, that the specification of harmonic category falls somewhere within the root, that specification will count as the "closest" occurrence of F. In (d), the vowels of both ma- and gɛ: are invariant, as these affixes are opaque. Therefore, the domain is iu. Accordingly, just as before, the domain receives the value of the F associated with the root. Finally in (e), as the initial root vowel is opaque, only the prefix vowels constitute the domain. The specification associated with the low vowel ɜ is "closer" to the domain than that associated with i; hence the domain agrees with the low vowel.^{4}

We now turn to the suffix case (3c):

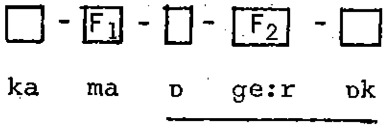
(f) (Turkish) *[gel-]iyor-um*

Here there are two domains, separated by the opaque vowel *o*. By case (3c), the first domain agrees with the occurrence of F associated with the root, and the second domain agrees with the occurrence of F on the opaque vowel to its right.

Finally, let us consider case (3d):

(g) (Kalenjin) ka-ma-ɒ-[ge:r]-ɒk

In this final example from Kalenjin, the domain includes a prefix, a stem, and a suffix (the domain constituted by the initial prefix is not in question). This example has the following structure, where morphemes are represented as rectangles, and the domain is underlined as above:



By case (d), the underlined domain agrees with the "closest" occurrence of F unordered with respect to it. As there is only one such F, namely F_2, the domain acquires this value.

As the last example shows, (3) would not permit a unique choice of F if more than one F can be unordered with respect to a domain. As we shall see below, an important property of vowel harmony is that this situation never arises.

We have not yet discussed how the principle of root control (3) applies to the case of nonharmonic roots, such as Finnish *afääri* 'affair'. One alternative would be to say that each vowel is fully specified lexically for the harmony-characterizing feature. Accordingly, we would say that all its vowels are opaque, and therefore no sequence of them forms a domain. On the other hand, we might want to integrate such roots into the description of harmony, insofar as they show subregularities. In the present case, three vowels agree in category, the two vowels *ää* and the neutral vowel following. The irregularity of this root therefore is evidenced only in the transition from the first vowel to the second. We might therefore stipulate that each member of a neighboring pair of root vowels which disagree in harmonic category IDIOSYNCRATICALLY, that is, in a manner unpredictable from morpheme structure conditions and the like, is an opaque vowel. This rather arbitrary choice permits a generalization of (3) to forms such as *afääri-ä*, in which it can now be said that the sequence *äriä* (containing no opaque vowels) constitutes a domain. As the nearest occurrence of F occurs on the second vowel of the word, this value is chosen. This extension of the concept "domain" into certain harmonically irregular roots may be useful in providing a relative measure of the irregularity of such forms, as we shall see in Chapter 3.

In this section it has been argued that vowel harmony, as it applies to both roots and affixes, can be subsumed under a single pretheoretical generalization, statement (3). This statement applies to roots and affixes alike, and correctly describes examples that had previously been thought to constitute proof that no single generalization was possible. For example, the Akan form o-bisa-ɪ discussed in section 2 has the following analysis:

$$\underset{(a)}{\underline{\text{o - [bi}}}\text{sa] - }\underset{(b)}{\underline{\text{ɪ}}}$$

The vowel a is opaque, by phonological rule (specifically, MS rule). Domain (a) agrees with the underlying specification [+H] associated with the initial root vowel i. And domain (b) agrees with the underlying specification [-H] associated with the final root vowel a. These results follow from (3), and do not require special statements for roots and affixes.

How, then, is this generalization to be captured in a segmental theory? The assumption that vowel harmony is segmental entails the position that each feature determining harmony in a given word is a component of a given segment. But then it must be determined WHICH segment such a feature belongs to. Thus one is forced either to make an arbitrary decision which cannot be justified on either language-particular or theoretical grounds, or to stipulate that all segments are fully specified. If the latter course is taken, a new problem of arbitrariness arises, that of determining the fully specified form of alternating vowels; and on the other hand, roots and affixes can no longer be treated in terms of a single statement. One must conclude that a segmental approach to vowel harmony cannot capture generalization (3) in any natural, nonarbitrary way.

4. It will be clear by this time that any adequate theory of vowel harmony will require a set of rather specific conventions determining how harmony domains are controlled. In particular, principle (3) should follow as a consequence of the structure of the theory.

It would be interesting, therefore, to consider a possible solution to this problem which, accepting the need for such conventions, attempts to account for the control of domains in terms of the principle of cyclic application. The model in question was developed by Kaye for the treatment of nasal prosodies in Desano (Kaye, 1971).[5]

We shall assume for the sake of this discussion, that in words characterized by vowel harmony, the root is the most deeply embedded element, and each affix forms a new cycle. A rule of vowel harmony applying cyclically will then first apply at the level of the root, and then to each successive layer of affixes in turn. In this way the harmony category of the root will propagate outward in a wave-like pattern to the increasingly peripheral affixes.

However, in languages with vowel harmony, we have seen that certain affixes may have opaque vowels. A similar situation arises in Desano, in which certain affixes may be inherently nasal. We wish, therefore, to prevent the values of these opaque forms from propagating inward toward the root.[6] Kaye proposed as a special convention that at the end of each cycle, all morphemes lying within that cycle are marked with a minus rule feature for the rule in question. As a result, these morphemes cannot be affected by later cycles.

4.1. Let us consider how this model would apply to examples of harmony in Igbo.[7] In Igbo, as in Akan, harmony is based on the category [ATR], the [+ATR] vowels (i, u, e, o) alternating with the [-ATR] vowels (ɪ, ʊ, a, ɔ) respectively. Igbo verbal roots are for the most part monosyllabic. Bisyllabic verbs are compounds, and thus do not necessarily conform to harmony. It will be assumed here that the roots forming such compounds are separated by word boundaries, which define separate harmony domains.

Igbo makes extensive use of prefixing and suffixing. In the dialect described by Green and Igwe (Green and Igwe 1963, Green 1964), that of Ọ̀h̃ụ́h̃ụ́, all prefixes harmonize with the root. Suffixes are divided into two classes, high tone suffixes and low tone suffixes.[8] No suffixes bearing inherent low tone have been found to harmonize, while of those bearing high tone, some harmonize and some do not, depending in part upon the idiolect. If only harmonizing suffixes are present in a word, the word will show regular harmony; thus from the verbal root nʊ̀ 'to fire (pots)' one may construct, for instance m̀-nà-á-nʊ̀-ɔ̀-là.

Of the nonharmonizing high tone suffixes, some fail to show harmonic alternation under any circumstances (-kɔ́ 'collective'), some alternate optionally (-sɪ́ 'distributive'), and at least one - the suffix -té/-tá 'motion towards' - may alternate or not, depending on the phonological environment: the alternant -té occurs after all [+ATR] vowels except e, and alternant -tá occurs elsewhere:

cɪ̀-tá ákʊ̍	'fetch some palm nuts'
lɪ̀-té	'stand up'
zʊ̀-tá ánʊ̀	'buy some meat'
lù-té ma̍ɪ́	'buy some wine'
ghɔ̀-tá ʊ̍bhé	'pick up some pears'
dhò-té ákwà ébé à	'put the cloth here'
bhà-tá	'come in'
wè-tá jɪ̍	'bring (a) yam'

(Green and Igwe 1963, 71).

An alternating suffix immediately following an opaque suffix agrees with the latter, rather than with the stem vowel, in accordance with principle (3) above. Some examples follow, in which roots are bracketed, and opaque vowels are underlined:

a. ò-[zú]-tè-ghì yá 'he didn't meet him'

b. ò-[ké]-tà̱-ghɪ̀ ánʊ́ 'he didn't get a share of meat'

(Green and Igwe 1963, 125). In (b), -tá exhibits its opaque alternant as it follows e (see the rule above), and consequently the suffix -ghì/-ghɪ̀ exhibits the form ghɪ̀.

c. (ɔ́-sɪ̍ ʊ́nʊ́) á-[la̍]-bò̱-lè '(he says that you) are not to go yet'

d. (mádhʊ̀ nɪ́llé) è-[zù]-kɔ̱́-tá-á-lá '(all the people) have assembled'

e. ɔ́-[ka̍]-bè̱-dɪ̱́-lá 'it's worse now than ever'

f. (mà h̃á) é-[vʊ̍]-té-sɪ̱́-ghɪ́ ábɔ́ '(if they) don't bring the basket'

(Green and Igwe 1963, 117, 99, 95, 129). We see that the general rule that a nonopaque suffix vowel agrees with the nearest vowel to its left is strictly adhered to. Thus in (c)-(e) the final suffix -le/-la varies according to the preceding vowel, whether alternating or opaque; in (d) the suffix -tá/-té agrees with the root vowel to its left rather than with the opaque suffix vowel to its right.

A moment's study will suffice to show that examples such as (f) above pose a nearly insuperable problem for the theory of simultaneous application formulated earlier. We wish to be able to state the generalization that a maximal sequence of nonopaque vowels (a domain) containing the root agree in category with the inherent category of the root. For this we require a rule with two cases, the second being the mirror image of the first; the rule must further stipulate that the determinant vowel is a root vowel. Thus we might attempt to formulate the rule as follows, using a double slash to indicate mirror image application:

$$V \rightarrow [\alpha\text{ATR}] \;//\; \underset{\begin{bmatrix}\alpha\text{ATR}\\ +\text{root}\end{bmatrix}}{V} \;\; X \;\_\_\_\; Y \;(\;[-\text{VH}]\;Z\;)\;\;\#$$

But we can easily see that this rule defines no value for the final suffix vowel of the example, which must assimilate to the suffix vowel to its left. In order to achieve this result we must introduce an additional, otherwise superfluous rule.

In a related form of Igbo, described by Abraham (1967), we find that a difference in suffix order has grammatical significance. If the past suffix -rV precedes the suffix -ghí (which is opaque in this dialect) the notion 'self-benefit' is expressed, while if it follows, 'benefit of another' is expressed. Among other examples we find:[9]

a.	ṃ̀-[gbújɨ̀]-rí-ghí̱ óshíshí	'I did not cut down the tree for myself'
b.	ṃ̀-[gbújɨ̀]-ghí̱-rí yóóshíshí	'I did not fell the tree for him'

(Abraham 1967, 87). In both examples, the suffix -rV agrees in category with the vowel of the syllable to its left.

The dialect described by Abraham is different from the one described by Igwe and Green in that the inseparable subject proforms i-/ɪ-, o-/ɔ-harmonize with the vowel to the right obligatorily if that vowel is a root vowel, but optionally if it is another prefix vowel. Thus we find forms such as the following:

c.	í-shì-rì (*ɪ́-shì-rì)	'you cooked'
d.	í-gè-è-shí ɪ́-gè-è-shí	'you'll cook' "

e. ó-nè-è-bú 'he/she carries (habitually)'
ɔ́-nè-è-bú "

(Abraham 1967, 40, 46). The set of forms (a) - (e) provides a problem in this case not only for the simultaneous application theory, but also for the iterative application theory, as this model was described above. Such a theory will have to be extended by a theory of mirror image application, in order to handle the bidirectionality of Igbo harmony. Thus a convention can be established allowing an iterative rule to apply from right-to-left and then left-to-right, or vice versa. Let us suppose that such a convention is adopted; the forms (a) - (e) show that it will have to be interpreted in such a way that it starts with the ROOT vowel in each case. For otherwise, if the second case that applies under the mirror image convention applies from right to left, it will assimilate the rightmost root vowel of gbújɪ[10] to the final opaque vowel in (a); while if it applies from left to right, it will assimilate the entire string gè-è-shɪ́ of (d), nè-è-bú of (e) to the initial, opaque vowel of the second member of each pair.[11]

Let us consider a further proposal. Variables ranging over vowels will now be allowed, provided they do not intervene between the focus and the determinant;[12] this extension does not weaken the hypothesis that rules do not apply "at a distance", and is consistent with the iterative framework. A rule can now be written:

$$\underset{[-\text{root}]}{\text{V}} \rightarrow [\alpha\text{ATR}] \;//\; \underset{[\alpha\text{ATR}]}{\text{V}} \; C_0 \;\_\_\_\; X \;\;\#$$

where X does not contain a root vowel

The directionality is left-to-right, changing to right-to-left for the mirror image case. We can see that this formulation will give the correct results in the case of Igbo if we assign minus rule features to the opaque vowels. However, we can also see that this cannot be a general schema for rules of vowel harmony, as it applies only to affix vowels (necessarily, in order to prevent roots from assimilating to prefixes). A further rule (a morpheme structure condition or phonological rule, as the case may be) is necessary to account for root harmony. Thus such a simple, regular item as the Akan form o-fiti-i requires two separate statements to account for the four vowels, one for the root, and one for the affixes.

4.2. Let us therefore turn to the cyclic model proposed by Kaye, which offers us an attractive solution for the Igbo problem. It will derive the form é-[vù]-té-sɪ́-ghɪ́ as follows:

[[[E	[vu]	tE]	sɪ] [-VH]	ghI]		
	-				VH	cycle 1
	[-VH]				[-VH]	
e		e			VH	cycle 2
[-VH]		[-VH]			[-VH]	
-	-	-	-		VH	cycle 3
-	-	-	-		[-VH]	
-	-	-	-	ɪ	VH	cycle 4
-	-	-	-	[-VH]	[-VH]	
e -	vu -	te -	sɪ -	ghɪ		

On cycle 1 (the root cycle), vowel harmony is not defined, as there is only one vowel. By Kaye's convention, the root is marked [-VH]. On cycle 2, the affixes to the immediate right and left are scanned and assigned the value [+ATR] in accordance with the root. At the end of the cycle they are marked [-VH]. Cycle 3 is vacuous as the only morpheme scanned is already marked [-VH]. On cycle 4, the vowel of the rightmost affix assimilates to that of the opaque affix to its left. Finally, it too is marked [-VH]. Crucially, it is the assignment of the feature [-VH] to the suffix te at the end of the second cycle that prevents it from being assimilated to the vowel to its right. We thus have a principle that captures the generalization expressed in (3).

This model extends to other examples discussed earlier, at the cost of a certain number of arbitrary decisions imposed by the linearity of the representations. Thus, the Akan example o-fiti-i poses no problem other than that of justifying one particular representation of the root morpheme over another.

This theory would appear to stand a chance of salvaging the segmental treatment of vowel harmony, until we look at a new set of data from Turkish, involving the interaction of vowel harmony with another rule affecting the same vocalic features.

In certain forms of the Istanbul dialect of Turkish, Rounding Harmony is reported to interact with a rule of Palatal Umlaut (Kumbaraci 1966, Lees 1967). In Lees' formulation of the rule, "a short vowel is unrounded immediately before a palatal /*y*, *ş*, *j*, *ç*, *c*/ within word boundaries if morpheme final or not in the first syllable of the word and it is, moreover, also raised if that palatal is followed immediately by a vowel" (Lees 1967, 289-90). Some dialects have only the second change carried out by this rule; however we will be concerned with the dialects having the unrounded case (all of which have the raising case as well). Some examples, which show the interaction of Rounding Harmony and Palatal Umlaut, follow:

(a) */okI-mIş/* → *oku-mɨş* 'is said to have read'

(b) */üşI-yIş/* → *üşi-yiş* 'feeling cold'

(c) */gümIş-tIr/* → *gümiş-tir* 'it is silver'

The problem is to determine the relative order of application of Rounding Harmony and Palatal Umlaut. We must keep in mind that in order to show that the cyclic theory under discussion is capable of solving the problem at hand, we must show that it is able to capture all generalizations about vowel harmony, within roots and across affixes, in a single rule. It must therefore account for root harmony in the examples under discussion, as well as affix harmony.

If we assume that the rules of the grammar are totally ordered, then (a) - (c) can be derived by ordering Rounding Harmony before Palatal Umlaut. Here, we assume that both Rounding Harmony and Palatal Umlaut are cyclical; however, Kaye's minus-rule-feature convention only applies to Rounding Harmony.[13] In (a), Rounding Harmony accounts for the final rounded vowel of the root on the root cycle; Palatal Umlaut is not defined. On the affix cycle, Rounding Harmony first rounds the affix vowel, and then Palatal Umlaut unrounds it; if we assume the opposite order, we would incorrectly have a final rounded vowel. Example (b) is similar. As for example (c), we must disagree with Lees who concludes that Rounding Harmony must apply last, contradicting the ordering assumed earlier. On the root cycle, Rounding Harmony first rounds the final root vowel, and then Palatal Umlaut unrounds it. On the affix cycle, the affix vowel is unrounded by Rounding Harmony, giving the correct form. (Notice, however, that if cyclic application is not assumed, Lees' observation is correct: the ordering would have to be Palatal Umlaut - Rounding Harmony, creating an ordering paradox.)

Now let us consider the further examples:

(d) */ütI-yI/* → *üti-yi* 'iron' (acc.)

(e) */dur-IyIm/* → *dur-ɨyɨm* 'let me stop'

For these examples, the assumption that Rounding Harmony precedes

Palatal Umlaut gives the incorrect result. The derivations follow:

	ü	*t*	*I*	-	*y*	*I*		
			ü				RH	cycle 1
			-				PU	
	[-RH]		[-RH]				[-RH]	
						ü	RH	cycle 2
			i				PU	
						[-RH]	[-RH]	
*	*ü*	*t*	*i*	-	*y*	*ü*		

	d	*u*	*r*	-	*I*	*y*	*I*	*m*		
		-							RH	cycle 1
		-							PU	
		[-RH]							[-RH]	
					u		*u*		RH	cycle 2
					ɨ				PU	
					[-RH]		[-RH]		[-RH]	
*	*d*	*u*	*r*	-	*ɨ*	*y*	*u*	*m*		

These examples, whether treated cyclically or noncyclically, pose a serious problem for segmental approaches to vowel harmony as they have been discussed to date. It is nevertheless the case that all of the examples discussed conform to the earlier informal characterization that was given of vowel harmony domains in (3). We note that a vowel subject to Palatal Umlaut has its value for a particular harmonic category stipulated by a rule of the grammar; it thus falls under the definition of an opaque vowel. As an opaque vowel occurring in a suffix, it does not necessarily agree with the vowel(s) to its left; however, the vowel to its right must agree with it. If the notion of 'opaque vowel' can be given theoretic status, then it should be possible to explain the Turkish examples in the same manner that the behavior of other opaque vowels is accounted for.[14]

We return to a discussion of these examples, in a nonlinear framework, in Chapter 3, section 7.

5. The present section is an excursion into an interesting and relatively unfamiliar topic that completes our brief overview of some of the descriptive problems posed by vowel harmony. Unlike the previous cases,

we are now dealing with a phenomenon whose formal description appears simple to the point of triviality, but which proves quite puzzling in the context of approaches which view vowel harmony as an essentially ASSIMILATORY process.

In work on a variety of East African languages, A. N. Tucker and others have identified a phenomenon which they term CATEGORY SHIFT. This is described as a process according to which the root vowel(s) of a word, and any attached weak (i.e. nonopaque) affix, change their harmonic category. This shift in category may be conditioned by morphological factors.

In the Nandi-Kipsigis group of Kalenjin, vowel harmony opposes a set of relatively open vowels to a set of relatively close vowels: thus the members of the set (ɪ, ʊ, ɛ, ɔ, a) alternate with the corresponding members of the set (i, u, e, o, ɒ).[15] In Kipsigis, the change of a root from the [-ATR] category to the [+ATR] category is described as the main way of expressing the 'motion towards' idea, otherwise expressed by means of the weak (nonopaque) suffix -ʊ(n)/-u(n): kɛ̀·-tɛ́m 'to dig', kè·-tèm 'to dig in this direction' (notice also the change of tone; the first morpheme in these examples is the infinitive prefix). Compare the imperative, in which both 'category shift', tone change and suffixation are observed: tɛ́m 'dig', tem-ún 'dig in this direction'. Category shift and suffixation combine in derived verbs formed with the derivational affixes -ji, -i·s: ke·-tem-jí 'dig for or at', ke-tem-í·s 'dig occupationally' (Tucker 1964, 468).

Category shift is also a means of deriving plurals from singulars in Kalenjin. Thus we find the following forms in the Nandi-Kipsigis dialect:

SING.	PL.	
tàrɪ́:t	tɒ̀rí:t	'bird'
nyɪ̀:rɪ̀:t	nyì:rì:t	'chameleon'
ŋɛ́lyɛ́p	ŋélyèp	'tongue'

We also find that the singular and plural can be related in the opposite direction; a [+ATR] singular form is associated with a [-ATR] plural form:

SING.	PL.	
lê:l	lɛ́l-àc	'white' (Nandi-Kipsigis)
sɒ̌·sû:r-wä̀ʔ	sà·sʊ̌:r	'banana' (Pakot)

(see Tucker and Bryan 1962, 179; 1964, 198).

The following forms illustrate the association of a shift of root category with an inflectional category, that of continuous (or noncompletive) aspect. Compare the simple 'today'tense form ká:-gû:t 'I blew it (today)' (Nandi) with the corresponding continuous form kɒ́:-gú:t-é 'I was blowing it', from the root ku:t 'blow' (Tucker 1964, 459, 466).

In the case of the singular-plural oppositions in Nandi-Kipsigis, we find that the grammatical distinction is signalled uniquely by the change in root category. In the remaining sets of oppositions, as Tucker points out, there are two alternative analyses. In the case of the continuous form cited just above, for example Tucker notes:

> One might argue that the suffix -e (...) is a strong [in our terms, OPAQUE - GNC] suffix causing Umlaut of the Stem vowel, or alternatively, that the Category Shift is purely grammatical (like the tense forms of Strong Verbs in English and German, and, therefore, an example of Ablaut), and that the suffix, being weak, takes a close vowel accordingly. (Tucker 1964, 470)

In fact, on the basis of the data given in these articles, there appear to be no grounds for deciding between these alternatives.[16]

The grammatical use of vowel harmony involving a change in root harmony class is a fairly widespread phenomenon. A few further examples follow.

In Manchu, we find that Category Shift is used for derivational purposes. The vowel series (*a*, *o*, *ô*) is associated with 'strong' or 'masculine' roots and stems, and the series (*e*, *u*) with 'weak' or 'feminine' roots and stems. The vowel *u* is neutral after nonback consonants, and *i* is neutral everywhere. Thus we find such pairs as *haha* 'man', *hehe* 'woman', *ama* 'father', *eme* 'mother', *naca* 'wife's elder brother', *nece* 'wife of wife's elder brother', *nakcu* 'maternal uncle', *nekcu* 'wife of maternal uncle', *amila* 'cock', *emile* 'hen'. Furthermore we find that this morphological process once resulted in new forms: from *arsalan* 'lion', the new form *erselen* 'lionness' was derived; from *habtaha* 'man's girdle', *hebtehe* 'woman's girdle'; from *ganggan* 'strong', *genggen* 'weak'; from *hôwaśan* 'Buddhist monk' (< Chinese *ho-shang*), *huweśen* 'Buddhist nun' (Haenisch 1961, 34). The use of this process to derive new forms indicates that it was at one time productive in Manchu.

A further derivational use of Category Shift has been cited from Hungarian (Lotz, 1972).[17] In standard literary Hungarian, if a root contains back vowels, back vowel suffixes are selected; if a root contains front vowels, front vowel suffixes are selected. The vowels (*ī*, *i*, *ē*, *e*) are neutral. Monosyllabic roots containing only neutral vowels normally select front vowel suffixes. However, there is a class of some fifty roots that exceptionally select back vowel suffixes (Rice 1967, Lotz 1972, Vago 1974). Of the latter class, Lotz reports that if a form is used not as a common noun but as a name, the FRONT vowel suffix is selected. Thus we find distinctions such as vīg 'gay', vīg-bɔn;

VĪg 'the name of a theater or person', VĪg-bän. Here, then, Category Shift is associated with the distinction between common nouns and proper nouns.

We find a unique situation in the vowel system of Spanish as spoken in Eastern Andalucía (see Rodríguez Castellano and Palacio 1948, Alonso, Zamora Vicente and Canellada de Zamora 1950, Zamora Vicente 1967). In contrast to the five vowel system (i, u, e, o, a) of Standard Castilian, these varieties of Spanish have obtained a ten-vowel system by a process of "vowel split" (*dédoublement*), according to which each Castilian vowel has split into an open and close variant. The cause of this split, historically, appears to have been the weakening (through aspiration) and loss of final s: s > h > 0. This phoneme constituted, or formed part of, certain grammatical suffixes, in particular the personal endings -s, -mos, -is, and the plural suffix -s. As final s was weakened and lost, the grammatical distinctions were maintained by means of vowel quality, the more open variants of the vowels occurring in forms which had final aspiration. The remarkable aspect of this 'phonologization' of the previously subphonemic vowel height distinctions is that vowel quality contrasts may characterize the entire word, rather than the final vowel alone. Thus we find such contrasts as the following: the dot indicates the higher variant, and the cedilla the lower variant:[18]

SING.	PL.	
pẹ́sọ	pȩ́so̧	'weight'
mọmẹ́ntọ	mo̧mȩ́nto̧	'moment'
bọ́kạ	bó̧ka̧	'mouth'
sẹrẹ́sạ	sȩrȩ́sa̧	'cherry'
mọlínọ	mo̧líno̧	'mill'
ẹ^{h}kọpẹ́tạ	ȩ^{h}ko̧pȩ́ta̧	'rifle'
kọlšọnẹ́rọ	ko̧lšo̧nȩ́ro̧	'mattress-dealer' (kolš+on+er+o)
kọmẹ́rlọ	ko̧mȩ́rlo̧	'eat it/them' (kom+e+r+l+o)

As these examples indicate, the harmonic shift normally affects the entire word, and crosses morpheme boundaries. Pretonic vowels are affected as well as tonic and post-tonic vowels.

The verbal system is also affected by category shift, so that those forms which formerly had final aspiration (from final s) now have vowels of the open series. Cf. the following paradigm of *tener* 'have' in the present indicative, given by Zamora Vicente (1967, 294):

		ORTHOGRAPHIC	PHONETIC
	1.	*tengo*	tẹ́ŋgọ
sing.	2.	*tienes*	tjé̞ne̞
	3.	*tiene*	tjẹ́nẹ
	1.	*tenemos*	te̞né̞mo̞
pl.	2.	*tenéis*	te̞né̞i̞̯
	3.	*tienen*	tjẹ́nẹŋ

These vowel shifts extend as well to singular nouns ending in historical s, such as tos [tó̞] 'cough', voz [bó̞] 'voice', tesis [té̞si̞] 'thesis'.

Not all vowels are affected in equal degree by the vowel opening process. First, high vowels seem to be little, if any, affected. Secondly, the low vowel *a* is little if any affected in nonfinal syllables, although the phonetic transcriptions given in the sources are not unequivocal in this respect. Third, vowels preceding *a* are normally unaffected, retaining their closer variants. There are further, more local variants noted for which the original sources should be consulted. With these qualifications, it is evident that vowel opening is a "harmonic" process in Eastern Andalucían Spanish that (when the appropriate conditions are satisfied) takes the entire word, including phonologically clitic material, into its domain.

The examples we have discussed in this section show that vowel harmony may be grammatically conditioned in some languages, serving to indicate the presence of one or more grammatical categories. Clearly, vowel harmony of this type cannot plausibly be viewed as involving the assimilation of one vowel to another. Rather, all vowels falling within the domain of the relevant grammatical categories 'shift' in their harmonic category: the conditioning factor in these cases is grammatical, not phonological.

6. In this chapter we have examined a number of segmental (i.e. linear, nonprosodic) approaches to the treatment of vowel harmony and have found that they raise a number of formal problems that do not find ready solutions within "standard" interpretations of generative phonology. It cannot be claimed that the present conclusions FALSIFY the standard framework as this has been interpreted by phonologists concerned with vowel harmony; indeed, the standard framework appears to be sufficiently unconstrained as to allow virtually any phonological phenomenon to be described in some manner, however arbitrary. The claim, rather, is that the standard framework does not permit well-motivated treatments of vowel harmony once a range of more complicated vowel harmony systems is examined in detail: rather, it must take recourse to formal devices

which allow the description of vowel harmony systems at the cost of expanding the descriptive power of the theory to an undesirable and unjustified extent.

To the extent that this negative conclusion is warranted, we have succeeded in demonstrating that prosodic approaches *per se* have not been discredited. In Chapter 1 it was argued that the problem underlying previous accounts was not their insistence upon prosodic treatments, but rather their insistence that even prosodic analyses should be carried out within LINEAR models of phonological representation. In this chapter, it has been argued that linear, NONPROSODIC treatments give rise to difficulties of another sort, requiring formal devices of undesirable power. Given these results, it would be of interest to explore the descriptive possibilities of a prosodic approach which exploits the potential of nonlinear phonological representation. This provides the subject of the next chapter.

NOTES TO CHAPTER 2

[1] In an earlier formulation (Clements 1974), principle (2) was called the WAVE principle. The following, generalized version has benefitted from the criticism of J. M. Stewart.

[2] Theories of simultaneous rule application are presented in Chomsky and Halle (1968), Vergnaud (1972), and Anderson (1974); specific applications to vowel harmony include Bach (1968), Schachter and Fromkin (1968), and Kiparsky (1968). Iterative theories of rule application are discussed in Johnson (1972) and Howard (1972); discussion related to vowel harmony includes Lightner (1972), Kiparsky (1973), Vago (1973) and Kenstowicz and Kisseberth (1973). Rather than trying to discuss each variant of these two approaches in detail, I will present a single version of each one.

[3] Descriptions of various aspects of vowel harmony in Turkish can be found in Kumbaraci (1966), Lees (1967), Lewis (1967), Foster (1968), Zimmer (1969), and Lightner (1972).

[4] It will be recalled that the low vowel acquires the phonetic value ɜ = [æ] only after the phrase-level rule of Metaphony applies.

[5] Strictly speaking, Kaye's model is a linear prosodic model of the type proposed by Williamson and Stewart, since nasality is formally represented as a prosodic feature N linearly ordered with respect to phonemic segments. However, within the present exposition, its consequences are of particular interest for the segmental approach, and it is therefore discussed here.

[6] This cannot be prevented, for instance, by the principle of the strict cycle (Kean 1974) since in the relevant configurations the rule makes crucial reference to an element in the highest cycle: the opaque vowel.

[7] The following discussion is based on data presented in Green and Igwe (1963) and Green (1964) except as otherwise noted. I have replaced the orthographic forms *ị*, *ụ*, and *ọ* with ɪ, ʊ, and ɔ, respectively.

[8] Surface tone does not necessarily reflect underlying tone; see in particular Goldsmith (in preparation). Thus low tone on a suffix in a given context does not necessarily indicate low lexical tone. In the tonal transcription, v́ is high tone, v̍ is "mid" (downstepped high) tone, and v̀ is low tone.

[9] The tonal notation has been changed to conform with the notation of the earlier examples; see note (8) above.

[10] Only the rightmost root vowel is affected, since gbújɪ̍ is a compound.

[11] Some writers attempt to account for the irregular behavior of suffixes through the manipulation of boundaries. Insofar as this use of boundaries is not motivated by independent evidence, it simply provides a way of encoding exceptionality in terms of boundaries, constituting a form of the "diacritic use of phonological features" to which Kiparsky first called attention. There are many instances in which we know this approach is incorrect on a priori grounds, as within multisyllabic suffixes (cf. Turkish *-Iyor*).

[12] Here I use the terms "focus" and "determinant" in the sense of Howard (1972) without however meaning to imply any consequences for the prediction of directionality. In a rule of the form A → B / C ___, where C is an element to which A assimilates, A is the FOCUS, and C is the DETERMINANT.

[13] Alternative ways of applying the rules must be rejected. Suppose Palatal Umlaut is "last-cyclic" and ordered before Rounding Harmony; (a) cannot be derived. Suppose Palatal Umlaut is postcyclic (therefore applying after all applications of Rounding Harmony); (c) cannot be derived. Suppose we extend the minus-rule marking convention to Palatal Umlaut (and Palatal Umlaut is cyclic); (b) can't be derived.

[14] I will not discuss here a further model proposed at one time by L. Anderson (see Anderson 1968); for discussion see Johnson (1972, Chapter 6). As it happens, this model can derive the Turkish examples correctly, although it has not been successfully extended to other areas.

[15] The following discussion is based on published work by A. N. Tucker (see the references below). I use the symbol ɒ for the vowel which Tucker represents as æ, in conformance with Hall *et al.* (1974). ɒ is an unrounded half-open back vowel, acoustically similar to ɔ (see Tucker 1964, 452; Hall *et al.* 1974, 244). Tone is marked v́ (high), v (mid), v̀ (low), v̂ (falling), v̌ (rising); in citing forms in isolation I do not indicate tone.

[16] If on the one hand we found that Category Shift was constant through a certain paradigm in which the affix associated with the grammatical category in question shows suppletive forms or zero alternants, the grammatical analysis would appear more plausible. If on the other hand in a paradigm in which the formal expression of the grammatical category in question is not constant throughout, we find that Category Shift appears if AND ONLY IF a certain affix appears, the phonological analysis would be strongly suggested.

More conclusive evidence would be offered by a form of the following structure, in which R is a [-ATR] root, O a [-ATR] opaque suffix, and A the formal expression of the grammatical category in question: R - O - A. If the Category Shift is a form of Ablaut, affecting the form of the root, R will be [+ATR] and A will be [-ATR]; if however the Category Shift is phonologically determined by an inherently [+ATR] affix A, then the root will be [-ATR] in this example. I have found no examples of this structure in the literature.

[17] This article was brought to my attention by Paul Kiparsky.

[18] The vowel I have transcribed as ą is described by all the sources cited as fronted and open with respect to ạ. I have simplified the transcriptions somewhat, omitting details irrelevant to the point at issue. Alonso *et al.* are insistent on the role of vowel quality, rather than the (optional and infrequent) occurrence of postaspiration, in distinguishing the singular and plural forms: "La pérdida de la -s final es la que ha motivado el gran cambio de timbre vocálico que nos ocupa. No se oye nada, o es apenas ligeramente perceptible en los plurales. Se oye más en interior de palabra: ọrọ́ʰkọ 'Orozco'; eʰtúdio 'estudio', etc. No hay diferencia entre *la llave* y *las llaves*, a no ser la de timbre vocálico." (Alonso *et al.* 1950, 226).

CHAPTER 3

AN AUTOSEGMENTAL THEORY OF VOWEL HARMONY

1. I will propose in this chapter that vowel harmony is to be best treated within a nonlinear model of phonological structure. What I mean by "nonlinear" will become clearer once a particular theory of nonlinear phonological structure has been presented, in the next section. For the present this term may be understood as drawing a distinction between two broad classes of phonological models, in the following way. We shall say that a phonological representation is LINEAR if it can be exhaustively analyzed into an ordered sequence of units having no ordered subparts. Given this definition, we distinguish between linear and nonlinear models as follows:

> a model is LINEAR if all its phonological representations are linear; otherwise it is NONLINEAR.

A nonlinear model, then, is one that provides at least some nonlinear representations in its account of phonological structure.

From our observations of the structure of vowel harmony systems in a number of languages, we have gained an appreciation of some of the general characteristics of this phenomenon. Keeping this picture in mind, our general strategy will be to measure the success of our theory, not against the "data" - which, if we take this term in any interesting sense, are always determined by the theory - but against the valid generalizations which can be made about the object of our study.

2. In a number of studies, Goldsmith has outlined the general properties of a nonlinear approach to the description of prosodic phenomena.[1] While this approach has been applied primarily to the study of tone and intonation, it has implications for other phonological features that can be observed to spread themselves across domains longer than the segment, or which sequence themselves across single segments, in the manner of contour tones, or prenasalization. This theory has already received substantial support from the study of tone in a number of African languages. It provides an elegant formal means for capturing a number of descriptive generalizations, many of which had been suggested informally in earlier work,[2] but which had resisted integration within established theoretical frameworks.

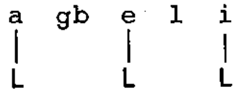
2.1. The basic claim of autosegmental phonology is that certain features and feature complexes, such as tone, behave with relative autonomy in regard to others. This behavior is reflected in a formal theory of phonology by representing such features and feature complexes on independent (but concurrent) levels of phonological structure. A full phonological representation will then consist of several independent strings of such segments. A formal relation of association binds elements of one level to those of another, and determines how they will be coarticulated.

Thus, in the description of tone languages, the feature complexes constituting tones will be assigned to a cooccurrent level of representation distinct from that level (or levels) upon which nontonal features are organized. Using L, M, and H as shorthand symbols for low, mid, and high tone respectively, we might have such lexical entries as the following:

(1)

The first representation describes a form in which the first vowel is realized with low tone, the second with high tone, and the third with a contour tone consisting of two elements, a mid tone element and a high tone element: this will be heard as a mid-to-high rising tone. The second representation describes an item with low tone on all syllables. In such a representation, the low tone is considered a single entity, in contrast to the theoretically possible alternative in which each vowel is associated with its own tonal segment:

(2)



The relation of association is expressed in terms of "association lines". As the examples of (1) show, association is not necessarily a one-to-one relation. Single segments may be associated with more than one tone, as in abolo, and single tones may be associated with more than one segment, as in agbeli. It is this characteristic that makes such representations nonlinear, in the sense in which we have been using this term: it is not possible to analyze the representations of (1) exhaustively into an ordered sequence of units having no ordered subparts.

Given such representations, it is possible to account for the relative independence of features such as tone with respect to the nonprosodic features constituting segments in the normal sense. Phonological rules applying to the elements of one level will not directly affect elements on another level unless a rule specifically designates such a result. This aspect of autosegmental phonology explains, for instance, the fact that rules which delete vowels do not in general affect the sequence of tones belonging to the word in which the vowel occurred: such deletion operations leave the tones intact, unless the rule specifically mentions them.

The formal relation of association does not bind tonal segments with EACH segment of the level upon which nontonal features are represented. This would clearly be incorrect, since for the most part nonsonorants do not bear tone in phonological representation. Rather, association is defined between tonal segments and certain designated elements of the nontonal level. In many languages these elements are the vowels; in other languages they include not only vowels but also other sonorants, such as nasals, liquids and glides, provided they occur in postvocalic position within the syllable. Since no universal statement can be given of the class of segments which may bear tone, these must be defined for each language. We may call these segments TONE-BEARING ELEMENTS.

In order to guarantee that all representations receive an unambiguous phonetic interpretation, a well-formedness condition is introduced for each pair of associated levels. Such conditions not only specify the set of well-formed associations, but also operate upon ill-formed representations by removing or adding the minimal number of association lines necessary to make the representation well-formed. In the case of tonal representations in "true" tone languages, this condition can be stated as in (3).

(3) (a) all tone-bearing elements are associated with at least one tone

(b) all tones are associated with at least one tone-bearing element

(c) association lines never cross.

As an illustration of the operation of the well-formedness condition in a derivation following the application of a rule, let us consider the following example, for Ewe. Ewe has a process of glide formation which may affect sequences of words as in the example below:

```
(4)  mʒ  +  kpɔ  +  e   →   mʒkpwe      'I saw it'
     M       H      L       M   HL
```

Here, the final vowel of the verb kpɔ becomes a glide before the following clitic pronoun. As a result, the high tone formerly associated with the verb shifts to the pronoun, which is realized with a high-to-low falling tone. Within the autosegmental approach, this process can be described as in (5) - (7) below. The initial representation in this derivation is given in (5):

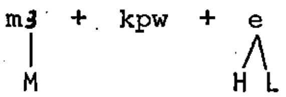
```
(5)  mʒ  +  kpɔ  +  e
     |       |      |
     M       H      L
```

To this representation the rule of glide formation applies (following a rule of stem vowel shift which need not concern us here):

```
(6)  mʒ  +  kpw  +  e
     |       |      |
     M       H      L
```

(6), however, is an ill-formed representation, since we find a tone associated with a segment which is not a tone-bearing element: the glide. Consequently, our formalism requires us to remove the line or lines which create the violation, here, the line connecting H and w. But the resulting configuration is still ill-formed, by (3b) of the well-formedness condition. Therefore we must draw the minimal number of lines necessary to make the representation well-formed, in this case, a line connecting H and e. This gives us the representation of the surface form [mɜ̄kpwê].[3]

(7)



In deriving (7) from (5), only one rule, that of Glide Formation, applied, yielding (6). The creation of (7) from the ill-formed (6) is completely determined by the formal structure of the theory. As Goldsmith has pointed out, the treatment of simple alternations such as the one above within a linear or segmental framework would raise a number of serious problems. Preceding the application of the glide formation rule (8b) there would have to be a rule which copies the tone of the about-to-be-deleted vowel onto the following vowel (8a):

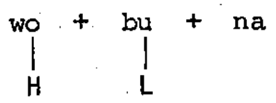
$$\text{(8)}\quad \text{a.}\quad [+\text{syl}] \rightarrow \begin{bmatrix}\alpha\text{high pitch}\\ \beta\text{low pitch}\end{bmatrix} \Big/ \begin{bmatrix}+\text{syl}\\ \alpha\text{high pitch}\\ \beta\text{low pitch}\end{bmatrix} \underline{\qquad}$$

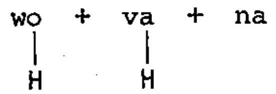
$$\text{b.}\quad [+\text{syl}] \rightarrow [-\text{syl}] \ / \ \underline{\quad}\ [+\text{syl}]$$

But this solution is highly problematical. First of all, as it stands, the rule of tone copying, (8a), does not give us the correct result: it will fail to create a contour tone, giving us the mapping $m\text{ɜ}_M kp\text{ɔ}_H e_L \rightarrow m\text{ɜ}_M kp\text{ɔ}_H e_H$ rather than the correct $m\text{ɜ}_M kp\text{ɔ}_H e_{HL}$. It is an open (and apparently irresoluble) question how (8a) might be modified within a linear framework to yield a contour tone in its output. Secondly, glide formation is not the only rule of Ewe which requires a rule of tone copying to precede it, in a linear approach. Ewe has several rules of vowel deletion, most of which[4] leave the original tone of the vowel behind. Each such rule would require its own associated tone copying rule, repeating the essential features of its environment, just as the tone copying rule (8a) above reflects the environment of the glide deletion rule (8b). There is a generalization being missed in this treatment: namely, the fact that rules which apply to nontonal segments generally leave the tone melody intact. This generalization cannot be easily captured within a linear model of phonological structure.

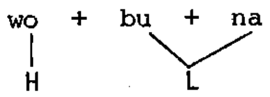
2.2. Let us now look at an entirely different aspect of tonal structure, in which the well-formedness condition again plays a central explanatory role. In tone languages we frequently find that affixes, or a certain set of affixes, behave quite differently from roots in the type of tonal alternations they display, in that their surface tone is always predictable from the context. In such cases, there are no grounds for assigning them one tone or another in their underlying representation. The simplest hypothesis we can make in such cases, and the one that involves the fewest unsupported assumptions, is that such affixes have in fact NO tone in their underlying representation: rather, their tone is acquired on the basis of the tones associated with neighboring elements, or according to other principles (such as those determining the tone melodies characterizing particular constructions or grammatical categories, etc.).

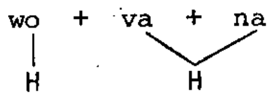
We may therefore allow certain morphemes to appear in the lexicon without any tonal assignment. The tone that such morphemes acquire will be determined by two sets of principles: one determining what tonal melodies will occur in the word or phrase in which the morpheme appears, and another determining how such melodies are sequenced across tone-bearing elements. In the simplest cases we might find underlying representations such as the following:

(9)


(10)


In (9), a hypothetical example, bu is a root with lexically specified low tone, wo is a prefix with lexically specified high tone, and na is a suffix which is inherently toneless. In (10), the structure is as in (9), except that the root va is specified for inherent high tone, instead of low tone. These representations, however, do not satisfy (3), and must be corrected accordingly, by adding the minimum number of lines such that a well-formed representation results. This can only be done by associating the root tone with the suffix, giving us:

(11)


(12)


In this way we have described the simple case of an affix which always agrees in tone with the element to its left.

The desirability of allowing some formatives to be entered in the lexicon with no tonal assignment shows that the well-formedness condition must not apply directly to lexical representations, but rather at some later stage, when formatives have become concatenated in strings representing full utterances. We will therefore have some lexical entries in which the value which a formative receives for some prosodic feature (autosegment) is not yet determined.

2.2.1. This situation may remind some readers of earlier theories of generative phonology in which lexical entries were not, in general, fully specified: in which, for instance, some segments received 0-specifications (null specifications) for certain features whose value was determined later in the derivation as a result of the operation of redundancy rules or phonological rules. It has been extensively argued, in a number of publications, that such representations should not be allowed, since they may, under certain circumstances, lead to SPECIOUS SIMPLIFICATION in the representation of morphemes: that is, to representations in which 0-specifications are allowed to function as a third type of feature specification.

Is the present theory of phonological representation subject to this criticism? There are reasons for believing that it is not. The structure of autosegmental theory is quite different from that of a segmental theory which allows 0-specifications, and there is no reason to suppose, in the first place, that arguments based on theories of the latter type should apply to theories of a quite different nature. Nevertheless, it is important to examine this point further, in order to show that the autosegmental approach does not amount to a notation which reintroduces zero-specifications in a new guise. In doing so, we will be able to gain a clearer view of the properties of autosegmental representation, and see how it represents a genuinely different view of phonological structure.

The argument will take two directions. The first is designed to show that it has never, in fact been demonstrated that a theory of phonology which allows blank feature specifications must allow these specifications to serve as third feature values. I will argue that such attempted demonstrations have rested upon a false view of the nature of MS (morpheme structure) rules. This argument will be carried out by stating a representative example designed to show the illicit use of zero specifications, and then showing that the crucial assumptions such arguments rest upon are not only extremely dubious, but also quite at odds with the views usually held of the nature of the operations that MS rules are able to carry out. Following this, it will be shown that whatever their success in the context of linear phonology, arguments of this type directed against the use of unspecified features in lexical matrices are inapplicable to autosegmental phonology, since autosegmental representations do not have the formal characteristics which serve as a necessary precondition for such arguments to go through.

2.2.1.1. Let us first, then, consider an example in which a zero-specification is used as a third feature value, distinct from both plus and minus, and which allows forms which are non-distinct in underlying representation to be distinguished through the application of rules. I summarize an argument first made by Lightner (1963). Suppose that a certain grammar contains, among others, the three MS rules given in (13) below and the three segments represented as in (14):

(13) i. +a → +c

ii. -a → +d

iii. +b → -a

(14)	(f)	(g)	(h)	
	+	0	-	feature a
	+	+	+	feature b
	-	-	-	feature c
	-	-	-	feature d

Two segments S_1 and S_2 are defined as DISTINCT if and only if at least one feature has a different specification in S_1 than in S_2. Thus, while (f) and (h) are distinct in (14), (g) is nondistinct from each one, since there is no feature in (g) that differs in specification in (f) or (h).[5]

Now let us consider how the rules of (13) affect these single-column matrices.[6] It must first be decided whether we are to allow rules defined upon a specified feature +F or -F to apply to matrices which are zero-specified (that is, unspecified) for F. In the present case, this involves deciding whether rules (13i) and (13ii) are to be allowed to apply to segment (g) or not. Let us first adopt a NARROW interpretation which stipulates that a rule defined upon a feature +F (or -F) may ONLY apply to a segment if that segment is itself characterized as +F (or -F, respectively). Under this interpretation, the rules of (13) will apply to the segments of (14) to yield the following derived forms:

(15)	(f)	(g)	(h)	
	-	-	-	feature a
	+	+	+	feature b
	+	-	-	feature c
	-	-	+	feature d

We see that (g), which was nondistinct from (f) and (h) in (14), is distinct from both in (15). In the derivation of (15), 0 has acted as "-" with respect to rule (13i) and as "+" with respect to (13ii); it has therefore acted as a third feature value.

Let us now consider the BROAD interpretation of rule application that will allow us to apply a rule defined upon a plus- or minus-specified feature to a segment which is zero-specified for that feature.

Under this interpretation the rules of (13) apply to (14) to yield (16):

(16)	(f)	(g)	(h)	
	-	-	-	feature a
	+	+	+	feature b
	+	+	-	feature c
	-	+	+	feature d

Once again, (g) has been differentiated from both (f) and (h). In this case, the zero-specification has acted as "+" with respect to (13i) and as "-" with respect to (13ii). Under whatever interpretation of rule application we adopt, therefore, the use of the zero-specification appears to lead to the creation of a third feature value.

There is another way of making this argument. One might let the theory allow us to write rules that apply ONLY to zero-specified features. For instance, instead of rules (13i) and (13ii) we might have the following:

(17) 0a → +c, +d

Rule (17) would then apply only to segment (g), and once again, (g), which is underlyingly nondistinct from (f) and (h), becomes distinct from both of them. (This, in fact, is the form in which the argument is given by Stanley (1967, 413-14) and by Anderson (1974, 284-5).)

Such arguments rest upon a set of questionable assumptions. The first relies crucially upon the notion that MS rules may change feature values. It can easily be seen that were this not the case, the forms of (15) (with their undesirable consequences) could not be derived from those of (14); in fact, segments (f) and (h) in (14) would be rejected as ill-formed. One must ask, therefore, whether this is a necessary or desirable property of MS rules.

It is difficult to find any support for the view that MS rules may change features in the literature on the subject. On the contrary, we find that MS rules are explicitly limited in function to the filling in of unspecified values:

> The morpheme structure or MS rules deal exclusively with the feature composition of individual morphemes. Their only function is to assign values to unspecified nonphonemic features. (Halle 1959, 55)

> The P rules may change feature values (...) they may add or delete whole segments, and they may permute segments. The MS rules, on the other hand, must not do any of these things; their sole function is to fill in blank entries with the proper values. (Stanley 1967, 398)

There appears to be no motivation for assigning MS rules a feature-changing capacity, and considerable reason NOT to do so: for to allow them this capacity would obliterate the conceptual distinction between MS rules, whose function is to account for redundancies in lexical representations, and P rules, whose function is to account for phonological alternations. The internal logic of the general approach characteristic of the generative phonology of the early 1960's requires that it insist rigorously upon the limited, blank-filling function of MS rules.

Let us return to the second form of the argument, based upon grammars allowing rules like (17). It is not hard to see where the trouble lies in this case: it is only within a theory which permits the use of zero-specified features in the structural description of rules that the problematical consequences could ever arise. There is clearly no motivation for assigning MS rules this power; moreover, such rules involve an overt use of zero specifications as a third feature value to begin with, and so it is hardly a surprise that zero specifications have served a ternary function after their application! The solution to this problem, quite clearly, is to disallow the use of zeros in the structural descriptions of MS rules.

It is therefore possible to reconstruct a constrained theory of MS rules which is consistent with earlier views regarding their form and function and which does not lead to inconsistencies deriving from the use of unspecified features. Such a theory would have the following properties:

(a) all MS rules apply before any P rules;

(b) MS rules only fill in unspecified features;

(c) zero specifications do not appear to the left of the arrow in MS rules.

These conditions will not exclude all derivations in which segments which are nondistinct underlyingly become distinct through the operation of rules; but such derivations are sometimes desirable, and there is no reason to exclude them provided they do not employ the zero-specification as a third feature value. (Examples of proposed cases in which the use of underspecified segments does not lead to the use of 0 as a third feature value have been discussed in Stanley (1967, p. 420) and in SPE (384-385) and will not be repeated here.) Thus, conditions (a), (b), and (c), while not ruling out all derivations which create distinct segments out of nondistinct segments, rule out the objectionable ones, and preserve the binary nature of a theory which allows 0 as well as "+" and "-" as feature specifications.[7]

Having reached this conclusion, I would like to point out that there may conceivably be independent reasons for excluding underspecified segments from lexical representations within linear theories of phonology. What I have tried to establish is not that we must allow underspecified segments, but only that the arguments for excluding such segments do NOT include what is often assumed to be the strongest of them, the argument based on the misuse of 0 as a third feature value.

2.2.1.2. The second line of defense against the charge that autosegmental phonology allows a covert reintroduction of underspecified segments (a defense which is, of course, superfluous if the first argument is valid) revolves around the notion of distinctness.

It will be recalled that in traditional generative phonology, two segments are said to be DISTINCT if and only if a feature has a different specification in one than it does in the other. We must now ask how this definition applies to autosegmental representations. In particular, we must inquire whether autosegmental phonology provides a category "segment", and if so, exactly what entity this term refers to.

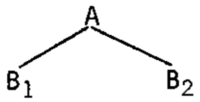
Up to now we have used the term "segment" to refer informally to feature bundles (single-column matrices) occurring on each tier, and there would not seem to be any reason to discontinue this usage. It might be objected that we are now using the term "segment" in a sense different from the traditional usage. In fact, while it is not always clear how traditional phonology defined the term "segment", the following formulation would be an accurate reconstruction of one common usage:[8]

> a SEGMENT is a unit of a segmentation, where a SEGMENTATION is the exhaustive, nonintersecting partitioning of an object 0 into a set of entities of category P.

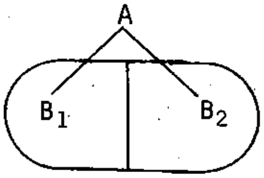
Consider, for instance the problem posed for traditional morphology by such items as the word *cranberry*. The morpheme is traditionally defined as the smallest unit bearing meaning. By such a definition, *-berry* is a morpheme but *cran-* is not. Nevertheless, faced with the problem of segmenting forms suchas *cranberry* into their morphological constituents, few linguists have shown any hesitation in classifying both {cran} and {berry} as morphemes. The reason for this practice is that the principle of segmentation functions as a higher-level analytical criterion. A morphological analysis of *cranberry* into a morpheme {berry} and some other, unidentified entity /cran/ is not an exhaustive partitioning of an object into a set of entities of category P, and therefore does not constitute a segmentation. In order for segmentation to be carried through, given the assumption that {berry} is a morpheme, one must consider {cran} a morpheme as well.

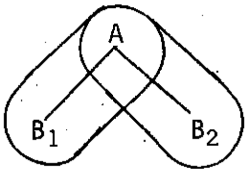
A similar argument might be offered to explain Bloomfield's decision to treat lexically distinctive tones as "phonemes" on a par with nonprosodic phonemes (1933, 116), or Jones' treatment of distinctive tonal, stress and length features as "tonemes", "stronemes", and "chronemes" in parallel to "phonemes" (Jones 1967). The problem here is that a phonemic analysis of a given linguistic form (morpheme, word, sentence) that ignores "suprasegmental" characteristics of speech serving a distinctive function will not be a segmentation, since it will not consist of a true partitioning. Once we recognize tonal phonemes and the like as elements of the partition, we cannot deny them status as segments.

If the above definition gives us an accurate reconstruction of the notion of segment, then it is clear that the feature bundles occurring along each autosegmental tier are segments in at least one traditional sense of this term. Consider, for instance, the following form, which might be the autosegmental representation of an affricate or of a vowel bearing a contour tone:

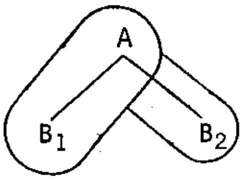


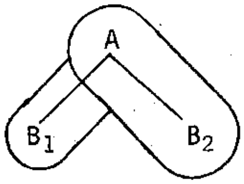
How is a segmentation to be carried out on this form? Since a segmentation is both exhaustive and nonintersecting, the following are ruled out:





But since a segmentation is also UNIFORM, in the sense that the entities P that result are of the same category, the following analyses are ruled out:[9]





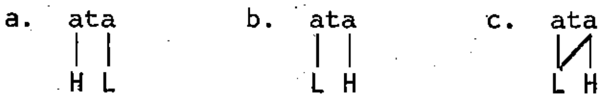
In short, the segmentation can only give us A, B_1, and B_2 as the resulting entities, and these must therefore be our segments.

We may now show that the relationship of distinctness, as defined upon the segments of traditional generative phonology, extends to the segments of autosegmental phonology as well. Let us consider in particular how the notion of distinctness is to be extended to formatives (morphemes). We wish to determine, for instance, which of the three morphemes represented in (18) are distinct and which are nondistinct:

(18) a. na b. na c. na
| |
H L

(a) and (c) are clearly to be treated as distinct forms; the problem concerns the status of (b). In a case such as this our theory does not impose one choice or the other. We have the option of deciding one way or the other, and we can only be guided by determining which choice yields the more desirable consequences. In this case the correct decision is clear. We are led to postulate the existence of toneless morphemes in the first place simply because they DO behave differently from tone-bearing morphemes; if it were not for their distinct behavior there would be no motivation for setting up this additional class of forms. We must therefore extend our notion of distinctness in such a way that (b) is stipulated to be distinct from (a) and (c).

Finally, we wish our relation of distinctness to class each of the following forms as distinct from the others:

(19)


We therefore arrive at the following account of distinctness:

(20) two representations are distinct if there is a segment occurring in one that does not occur (bearing the same relations of order and association) in the other.

According to this statement, (18a) is distinct from (18b) because there is a segment (H) occurring in the first that does not occur in the other. (19a) is distinct from (19b) because the segments H and L do not bear the same relations of order in the two formatives. Finally, (19b) is distinct from (19c) because the segment L does not bear the same relations of association in each case.

To return, now, to the question of whether autosegmental representations allow a disguised use of zero specifications (in e.g. the representation of forms such as (18b)), we are in a position to see that the argument based on the ternary use of binary features is simply inapplicable here. Let us consider the forms given in (18). While (a) and (c) consist of three segments, (b) consists of two segments. The distinction among these forms then is exactly parallel to the distinction among forms like *pat*, *at* and *bat*: *at* and *pat* are not nondistinct, since *pat* contains a segment, *p*, that is not contained in *at*. In a similar way, (18a) contains a segment, H, not contained in (18b). In short, the segmentation of forms (a) and (b) is not a segmentation into features, but a segmentation into entities that are themselves characterized by features: what distinguishes (a) and (b) is not in the first instance their features but rather the segments which comprise them.

We see, then, that quite independently of the success or failure of our first argument, autosegmental representations are not subject to the type of criticism that was earlier applied to theories permitting archiphonemes. It follows furthermore that since autosegmental phonology leads to no misuse of binary features, nor to derivations in which distinct forms are generated from nondistinct forms, there is no theoretical motivation for preventing feature-changing rules from applying to autosegmental representations. We shall assume, then, that a theory in which phonological rules apply to representations such as those of (18) is an internally consistent one.

2.2.2. To summarize, we have drawn two conclusions from our discussion of the distinctness paradox:

(a) Lightner's distinctness paradox does not, as has sometimes been thought, lead to the conclusion that lexical entries must be fully specified in their dictionary representations. It does, however, support the conclusion that morphemes must be fully specified by the time the first feature-changing rule applies, and that rules cannot be stated in such a way as to apply UNIQUELY to segments unspecified for certain features (see conditions (a) and **(c)**, earlier);

(b) there is no comparable restriction on rule application to autosegmental representations containing such forms as "toneless" morphemes. Feature-changing rules can be permitted to apply to such forms without involving the ternary use of binary features.

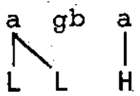
In regard to the second conclusion, only limited use is made of the freedom we have obtained. We adopt the common assumption that morpheme structure rules (or conditions), rules of word formation and perhaps other rules of the morphology apply to forms BEFORE the well-formedness condition (3) and the rules of the phonology come into effect. On the other hand, the well-formedness condition applies at each level of derivation thereafter: that is, at the level at which the first phonological rule applies, and to the representations resulting from each further rule application. As a result, phonological rules will never encounter such forms as "toneless" suffixes.

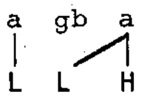
2.3. One further aspect of autosegmental phonology should be mentioned before we turn to a closer study of the way such a theory will apply to the description of vowel harmony. This concerns the manner in which the elements of different autosegmental levels are associated with each other. Let us consider the case of such possible lexical entries as the following, which contains a tone "melody" not yet associated with any segments of the upper level:

(21) $$\begin{bmatrix} \text{a} & \text{gb} & \text{a} \\ \text{L} & \text{L} & \text{H} \end{bmatrix}$$

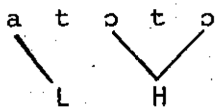
(22) $$\begin{bmatrix} \text{a} & \text{t} & \text{ɔ} & \text{t} & \text{ɔ} \\ & \text{L} & & \text{H} & \end{bmatrix}$$

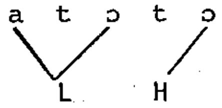
Clearly, if the well-formedness condition is to determine the way these two levels are associated, it will not give a unique result. There are two possible applications to (21):





and two possible applications to (22):





As these examples show, the well-formedness condition must be supplemented by principles that determine how the elements of different levels are to be associated with each other, in cases where there can be more than two segments on each level. Current research into this topic, which includes Goldsmith (1974a), (1976b), Haraguchi (1975) and Liberman (1975), suggests that while these principles are to some extent language-particular, they are reducible to a few widely recurrent types, including "mapping rules" which map tones onto syllables from right to left in a one-to-one fashion across the morpheme, and rules which are sensitive to indications of stress; I will refer to these principles by the collective name "association rules". One characteristic of these rules is that they apply to representations before the well-formedness condition does; they must therefore be added to the list of rules given above which precede the "activation", or coming onto play, of the well-formedness condition.

2.4. In this section I have tried to present a brief, general picture of some of the principle aspects of a nonlinear approach to phonology, the autosegmental theory proposed by Goldsmith, and I have tried to show how this theory differs in very important respects from other approaches to phonological representation. The above sketch is based primarily on considerations of tonal phonology for tone languages, and will undoubtedly require modifications and extensions as other types of phenomena are investigated.

While the CONTENT of any particular version of this theory will vary, then, according to the nature of the phenomenon under study, its FORM is defined in all cases by the following notions (among, perhaps, others):

(23) (i) the notion "well-formed lexical representation", including a specification of the well-formed sequences of segments ("melodies") admissible on each autosegmental level;

(ii) the notion "association rule", which (together with the well-formedness condition) determines unique, unambiguous associations between the segments of related autosegmental levels;

(iii) the notion "well-formedness condition", which, as we have seen, has the dual function of characterizing well-formed associations between related autosegmental levels, and of monitoring the representations resulting from rule applications; and

(iv) the notion "reassociation" ("remapping") rule, that is, that type of phonological rule which carries out a change in the relationship between related autosegmental levels; these rules will insert, substitute, delete or rearrange segments, or simply alter the network of associations among existing segments.

Each of these notions is closely related to the others, and it is one of the major tasks of an autosegmental approach to define the proper sphere of each.

3. Vowel harmony is a natural testing-ground for the thesis that autosegmental phonology is not restricted to tonal phenomena, but constitutes a general theory of phonological representation. Outside of tonal processes, it is in vowel harmony that we find some of the strongest motivation for positing "an autonomous role for autonomous sound qualities" (Jakobson), and for treating distinctive features as independent entities in their own right.

3.1. In its simplest, most regular form, vowel harmony consists of a cooccurrence restriction upon the vowels that may occur in a word. All vowels in a word must be drawn from one or another of two mutually exclusive sets.

Even this simplest of principles has resisted completely satisfactory treatment within traditional, linear theories. Arbitrary choices had to be made as to the underlying specification of vowels in affixes, the underlying specification of root vowels, the location of the determinant for the application of vowel harmony rules, or (in the case of bidirectional harmony) the ordering of the cases of a given rule provided by the mirror image convention. Within some approaches (e.g. Anderson 1974, Vago 1973, 1974), separate, redundant statements had to be made for root harmony and suffix harmony.

The simplest case should be treated in terms of the simplest formal apparatus. Let us suppose that the features which serve as the basis for harmony are extracted and represented upon a separate, autosegmental level. To each regular root there corresponds one such feature, +F or -F.

Affixes are not specified for these features at any level.

Thus, the regular Akan verbal root fiti 'to prick' is assigned the feature +ATR, constituting an independent segment on a separate autosegmental level. It may enter a lexical representation with prefixes and suffixes:[10]

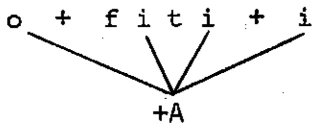
(24) O + f I t I + I

+A

(Here, and in the following representations, capital letters indicate segments that have not yet become bound to elements on related autosegmental levels. Thus, /O/ is a segment that will eventually be realized as [o] or [ɔ]; and /I/ is a segment that will eventually be realized as [i] or [ɪ]. To simplify the diagrams, single features will be represented by single capital letters, thus +A = [+advanced tongue root].)

In terms of the framework developed in the last section, no rule of the grammar will affect representation (24) until the point at which the phonological rules apply. At this point, the well-formedness condition comes into effect as a convention monitoring the form of representations prior to and after the application of each rule. In the terms of the well-formedness condition, (24) is illformed; consequently, the minimal number of association lines must be entered to satisfy the condition. The result is (25):

(25)

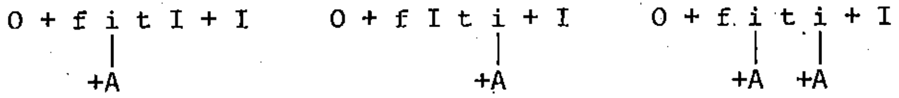


This gives us the correct surface form, o+fiti+i. This is simply the consequence of the lexical representation (24) together with an independently motivated convention of the theory.

In deriving (25), no mapping (association) rule has been introduced. Clearly such a rule would be superfluous. This, in fact, is one important respect in which vowel harmony differs from tone: there are no association rules for vowel harmony.

As the reader will undoubtedly have observed, (24) is not the only lexical representation that might have served as the source for the surface form o+fiti+i. Other theoretically possible sources are the following:

(26)



In selecting (24) rather than any of the forms of (26) as the source for the surface representation (25), we have made a rather natural assumption. Notice that the one formal entity that the present theory adds to phonological representation is the association line. In evaluating the relative complexity of representations, we shall assume that all things being equal, the representation with the smallest number of entities will be selected. This means that in representations such as those of (24) and (26), one counts NOT ONLY the number of segments, but also the number of association lines. While this principle is undoubtedly an oversimplification (and will be refined below), it gives the intuitively correct result in a number of cases. In the present case, it unambiguously selects the representation of (24) as the unique source of (25).

3.2. Before continuing to the examination of more complex, irregular types of vowel harmony, let us specify in somewhat more detail the structure of the formal representations that we are assuming.

The LEXICAL REPRESENTATION of a linguistic form consists of bracketed strings of concatenated formatives, some of which may be abstract (e.g., grammatical morphemes such as [+past]), and some of which consist of groupings of distinctive (classificatory) features. It is the latter type that will concern us here. These consist of a number of concurrent autosegmental levels, each of which consists of strings of concatenated SEGMENTS. Such segments are constructed from one or more features $F_1 \ldots F_n$. For instance, the segments constituting tones will be constructed of tonal features, and occur on one level only. However, boundary features have an exceptional status. By a general convention, if a boundary appears on one level, it appears concurrently on all the others, and all these occurrences are bound by association lines. For example, the full lexical representation of (22) would appear as:

(27)
$$\left[\begin{array}{ccccccc} \# & a & t & \text{ɔ} & t & \text{ɔ} & \# \\ | & & & & & & | \\ \# & & L & & H & & \# \end{array}\right]$$

The upper level in this representation consists of the concatenated string of units (boundaries and segments) #⁀a⁀t⁀ɔ⁀t⁀ɔ⁀#, and the lower level of the string of units #⁀L⁀H⁀#. (The conventions for introducing boundaries into representations will not be discussed here. They are outlined in SPE, 364-372 and in Selkirk 1974, 577-8.)

A unit on one autosegmental level is said to be BOUND if it is associated with some unit on a related level by an association line; otherwise a feature is UNBOUND. (In general, I use "bound to" as an equivalent term for "associated with".) In (27), the segments a, t, ɔ, t, ɔ, L, H are unbound, and each of the four occurrences of # is bound.

We shall now see how the useful notion of DOMAIN can be characterized within the present framework.

We generally find an asymmetrical relation holding between any two levels related by association: not all the elements of one are designated as "P-bearing elements" for the segments P of the other level. This is immediately apparent from our earlier discussion of tone. In (5), for instance, we saw a representation in which only vowels are tone-bearing elements ("P-bearing elements" for the level of tone). This is, in fact, the normal case. We generally find that given two related levels, L_1 and L_2, not all the elements of one (say, L_1) are bound to the elements of the other (L_2) in well-formed representations. In such cases, the set of "P-bearing elements" in L_1(where P represents the segments on L_2) must be stipulated. We shall accordingly call L_2 the P-LEVEL and L_1 the P-BASE. Thus, in (5), since some elements of the upper lever (i.e. non-vowels) do not bear tone, the upper level is the P-base, and the lower level is the P-level.

Given these preliminary distinctions, we can describe the domain governed by an unbound segment P belonging to a P-level in the following way. Let L_1 be a P-base and L_2 a P-level, and let U_1 and U_2 be any bound units (either segments or boundaries) of L_2 such that they are concatenated with P in the sequence $U_1 \frown P \frown U_2$. The DOMAIN governed by P is the string of unbound segments σ such that the left neighbor of σ is a unit U_3 bound to U_1, and the right neighbor of σ is a unit U_4 bound to U_2:

(28)
$$\begin{array}{lccc} L_1: & U_3 & \overbrace{S_1 \quad S_2 \quad \ldots \quad S_n}^{\sigma} & U_4 \\ & | & & | \\ L_2: & U_1 & P & U_2 \end{array}$$

Returning now to the example of regular vowel harmony that we discussed above, we see that (24), if given its complete formal representation as in (29), is an instance of the schema (28), where σ = the string O+fItI+I, P = +A, and U_{I-4} are the four word boundaries (brackets are omitted):

(29)
$$\begin{array}{ccc} \# & O+f\,I\,t\,I+I & \# \\ | & & | \\ \# & +A & \# \end{array}$$

Therefore, we can say that the unbound segment +A GOVERNS the domain O+fItI+I. The well-formedness condition performs a uniquely-defined operation upon such representations: it associates an unbound segment P with each P-bearing segment in its domain. Applying to (29), it yields a representation in which all segments are associated as in (25).

4. The above section shows how the simplest, commonest case of vowel harmony is treated within autosegmental theory. For this simplest case, the simplest formal means are employed. No rule of the grammar is involved in the derivation of ofitii; rather it arises solely from the operation of the well-formedness condition to the underlying representation (29).

In order for us to evaluate the correctness of an autosegmental treatment of vowel harmony, however, we must look at the more complex cases involving irregularity of various sorts. One of the most important tests that any theory of a given descriptive domain must pass is its ability to treat the apparent idiosyncracies of the data; a theory which is able to extract significant generalities from such irregularities is more adequate (all else being equal) than one which is not.

4.1. We have so far assumed that the features which govern harmony are not bound to any element of the P-base at the time of "activation" of the well-formedness condition. However, this is not necessarily true in all cases. There are two ways in which such bindings might already be present at the point of initial application of the well-formedness condition: they might be present in the lexical representation, and they might be introduced by rules of the morphology.

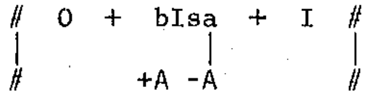
The essential proposal of this section is that OPAQUE segments are just those segments that are already bound to some element of the P-level before the phonological rules (and the well-formedness condition) apply. All properties of opaque segments follow from this proposal, given the framework established so far.

In Akan, as we argued in Chapter 1, the vowel *a* is everywhere opaque. Thus, it blocks the passage of harmony from roots to affixes, and governs a new harmony domain of its own:

(30)	bisa	'to ask'
	o + bisa + ɪ	'he asked'
	pạtiriʔ	'to slip'
	wʊ - bɛ-pạtiriʔ	'you will slip'

Regularities of this sort must be captured by morpheme structure conditions: we assume, then, that in the phonology of Akan there is a statement to the effect that every lexical occurrence of the low vowel is bound to an occurrence of the feature [+ATR]. (The form of such statements will be discussed below.) Accordingly, the second of the above examples will appear as follows in lexical representation:

(31)

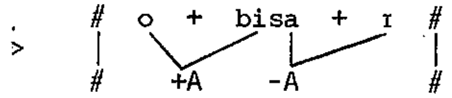


Now we must determine how the well-formedness condition applies to such a representation. There are two alternatives: either we spread from the bound feature first, or we spread from the unbound feature first. Obviously, the second alternative must be chosen, as it is the only one consistent with the phonetic form of this word. We therefore establish the following principle as a further clause to the well-formedness condition:[11]

(32) PRIORITY CLAUSE(A): unbound segments are associated before bound segments.

The well-formedness condition now maps (31) into (33):[12]

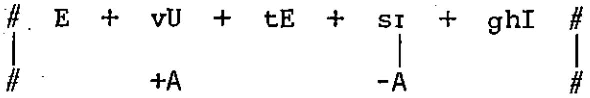
(33)



This treatment, it will be observed, provides a unified explanation of three superficially unrelated "irregularities": first, the fact that the vowel *a* does not alternate harmonically; secondly, the fact that the suffix agrees with *a*, rather than (as is logically possible) with *i*; and thirdly, the fact that the *i* of the root fails to assimilate to *a*. These facts follow by necessity from two assumptions that underlie our approach, namely, that representations are subject to the well-formedness condition, and that opaque segments enter the rules of the phonology BOUND to some segment P of the relevant P-level. Given these two general principles, and the observation that the low vowel is opaque in Akan, (33) is the only possible realization of (31).

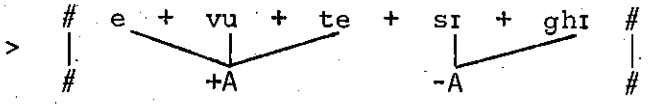
It would be natural to treat opaque vowels that occur in suffixes by means of the same principles that we have used for those that occur in roots. Let us consider the behavior of opaque suffix vowels in Igbo (cf. section 4.1, Chapter 2). The distributive suffix sɪ is invariant in shape, never harmonizing to the root category; furthermore, it controls the harmonic category of suffixes occurring to its right. We will suppose, therefore, that in lexical representation its vowel is bound to the feature [-ATR]. The full lexical representation of the phrase e-vu-te-sɪ-ghɪ '(if they) don't bring...' is therefore as follows (vU is the root):

(34)



According to Priority Clause (A), the unbound segment of the P-level spreads first, and therefore (34) is realized as (35):

(35)



4.2. In the above discussion we have seen two examples of opaque vowels that occur as such in the lexicon. This is not the only source of opaque vowels, however. Let us now turn to an example of an opaque vowel created by rule.

The adessive suffix -te ∿ -ta of Igbo alternates according to the principles of vowel harmony in most contexts. Thus, after a [-ATR] vowel it is realized as -ta; however, after a [+ATR] vowel it is realized as -te only if the preceding vowel is not *e* (see Chapter 2, section 4.1). After *e*, this suffix is opaque; compare for instance:

ò - zú - tè - ghì yá	'he didn't meet him'
ò - ké - tà - ghɪ̀ ánʊ́	'he didn't get a share of meat'

(Green and Igwe 1963, 125; zu and ke are roots).

The irregular behavior of the adessive suffix can be described in terms of a rule which binds its vowel to an occurrence of the segment -A after the formative ending in *e*. This rule can be stated as in (36) below. Here, I adopt the usual notational convention that inserted association lines are represented as dashed lines; the box indicates that the segment -A is inserted by the rule. Thus, (36) abbreviates the rule (37):

(36) $$\begin{array}{ccc} \mathrm{E} & + & \mathrm{tE} \\ & & \vdots \\ +\mathrm{A} & & \boxed{-\mathrm{A}} \end{array}$$

(37) $$\begin{array}{ccc} \mathrm{E} & + & \mathrm{tE} \\ & & \\ +\mathrm{A} & & \end{array} \rightarrow \begin{array}{ccc} \mathrm{E} & + & \mathrm{ta} \\ & & | \\ +\mathrm{A} & & -\mathrm{A} \end{array}$$

Since (36), referring to a specific formative, appears to be most properly included in the set of morphological rules, I assume here that it will apply before the well-formedness condition comes into effect. Thus the derivation of o-ke-ta-ghɪ will proceed in parallel to the derivation given in (34)-(35).

5. In order to provide an analysis of disharmonic roots, we must look briefly at the structure of lexical entries.

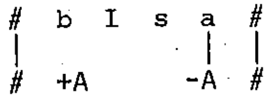
5.1. Within linear frameworks, the usual way of accounting for exceptional roots is to introduce rule exception features, stating that the root in question is an "exception" to vowel harmony. The same treatment is accorded to exceptional affixes.

Within the present framework, since vowel harmony is viewed as a consequence of general well-formedness conventions rather than as a set of language-particular rules, exceptions to harmony cannot be accounted for by such rule features. Rather, they must in all cases be built directly into the lexical representation of morphemes: vowels which invariably exhibit a given feature *F* are lexically bound to that feature or (in the case of roots) are always governed by that feature, unless (as in the case of neutral vowels: see below) there is an independent explanation for their failure to show surface alternation. In some cases this lexical binding conforms to a general segment structure condition: thus, in Akan, low vowels are (as we have seen) invariantly

[-ATR] and opaque, and are therefore lexically bound to the P-segment [-ATR]. In Turkish, all nonhigh vowels in a word other than the initial are (with occasional exceptions) nonrounded; thus these vowels are lexically bound to the feature [-round]. On the other hand, there are many exceptions to harmony that are simply unpredictable. Thus in Turkish, which has both backness and rounding harmony and no neutral vowels, the lexical roots *ziyaret* 'visit' and *pilot* 'pilot' are irregular.

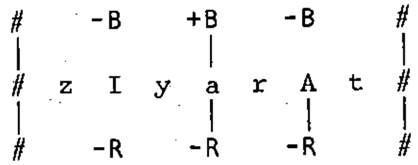
In accordance with this approach, we will find such lexical representations as the following:

(43)



(Akan)

(44)



(Turkish)

We shall assume, provisionally, that lexical binding which is predictable by morpheme structure conditions does not add to the complexity of lexical representations, but that unpredictable lexical binding does. We now see that there is a way to achieve a rough, but intuitively correct measurement of the complexity of a lexical representation. The method would be approximately as follows:

(45) a. eliminate from consideration all bound features the occurrence of which is predictable in terms of morpheme structure conditions.

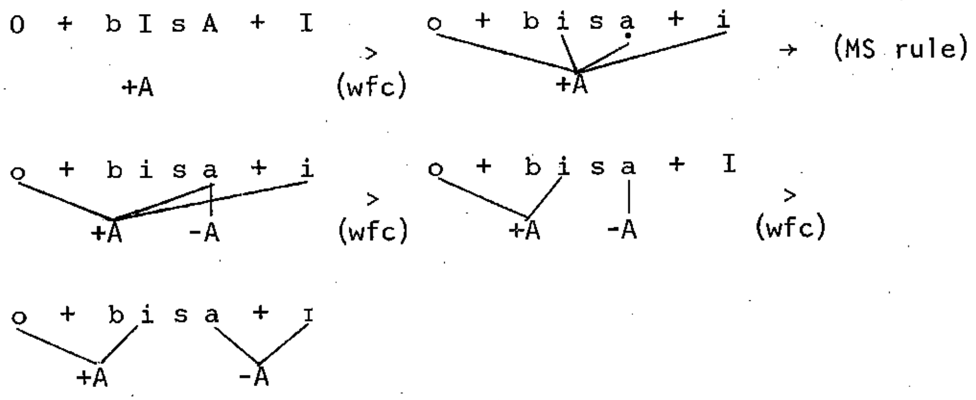
b. count the remaining instances of bound features in the representation.

The question arises of why the P-segment [+A] is not bound in (43), nor [-R] in (44). Since bisa is perfectly regular in terms of the phonological conditions which define the set of possible representations in Akan, and *ziyaret* is regular in regard to possible sequences of the feature ROUND on vowels, it would appear incorrect to penalize these representations. Therefore, by not binding features which are flanked on both sides by either a predictable feature or a morpheme boundary "+", we allow the evaluation procedure to reflect their relative regularity. Thus, according to (45), the complexity of (43) is 0, and the complexity of (44) is 1. Formulated in this way, the evaluation metric is able to distinguish between lexical binding which is stipulated by rule, and lexical binding which is arbitrary.

5.1.1. This approach to lexical irregularity is not, of course, the only conceivable one. As an alternative, we might consider the hypothesis formulated in the spirit of Lightner (1965) that lexical roots are assigned to only ONE harmonic category; lexical binding then takes place subsequently by rule. Thus, the morpheme structure conditions would, in the case of autosegmental representation, be replaced by morpheme structure rules that insert segments on autosegmental tiers: Akan would thus have a rule inserting the P-segment [-ATR], associating it with each low vowel, and similarly Turkish would have a rule inserting the feature [-round], associating it with each noninitial nonhigh vowel in the word. (Extending this approach to the case of arbitrary lexical exceptions, certain vowels would be marked with a rule feature allowing them to undergo a rule that would assign them their correct surface value.)

Let us see how the Akan example obisaɪ might be derived under this approach:

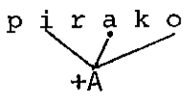
(46)



In this derivation, the application of the morpheme structure rule creates an ill-formed structure, to which the well-formedness condition must reapply, first removing the offending lines, and then reintroducing an association between the rightmost segment and the final vowel.

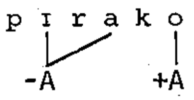
On the surface of things, this derivation might seem to be straightforward,^{13} until we consider further Akan examples such as the form pɪrạko. Here, it will be recalled, the vowel [ạ] is an allophonic variant of /a/, determined not by vowel harmony but by a later rule of metaphony. Thus, the proposed morpheme structure rule must apply to this vowel at an underlying level, binding it to the autosegment [-ATR], as we argued earlier. When the well-formedness condition has applied, however, we will have the following representation:

(47)

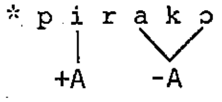


Now, exactly where is the morpheme structure rule to insert the autosegment [-ATR]? If it is to the left of [+ATR], we will derive (48a); if it is to its right, we will wind up, incorrectly, with (48b):

(48) a.



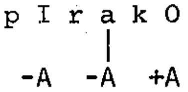
b.



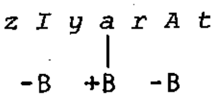
Since (48a) is the correct form, it must be the case that the morpheme structure rule in question inserts the feature [-ATR] to the LEFT of the inherent root feature. However, this result is wrong for (46), where (as we saw: cf. note 13) it must be inserted to the RIGHT.

We can easily see that such problems will be compounded once we consider forms such as (Turkish) *ziyaret*. By the feature-insertion hypothesis we are considering, this root would be assigned the feature [-back] in lexical representation, and the feature [+back] would be inserted on the vowel *a* by rule. But we can easily see that our formalism is incapable of giving us the correct result. Depending on how we formulate the rule, we will only derive **zɨyaret* or **ziyarat*. In short, this alternative seems entirely inconsistent with the present framework; it misses the point that opaque vowels FORM BOUNDARIES BETWEEN HARMONY DOMAINS. This aspect of opaque vowels follows clearly, however, from such representations as the following:

(49)



(50)



These facts provide strong support for our view that some roots appear in lexical entries with harmony features already bound to one or more vowels.

5.2. Rule-governed regularities obtaining between related autosegmental levels of lexical formatives will therefore be described in terms of morpheme structure conditions, in roughly the sense of Stanley (1967). Some morpheme structure conditions will be idiosyncratic to particular languages; we have already described some of these. Others, however, will be general conditions applying to all languages with vowel harmony. It is probably the case, for instance, that roots must always contain at least one harmony feature in their lexical entry, which of course may be either bound or unbound. This is a consequence of the principle of root control (cf. (3), Chapter 2); if some roots were not to contain any harmony feature, there would be no way of determining the category of the associated affixes. Clearly, such structures must be blocked. The theory must therefore provide a general condition on roots requiring each root vowel to meet one of the following two conditions:

(51) a. if V then $\begin{array}{c}V\\ |\\ \pm P\end{array}$

b. if V then $\begin{array}{ccccc}U & X & V & Y & U\\ | & & & & |\\ U & & \pm P & & U\end{array}$

(51) stipulates that each vowel in a lexical root must be either bound to some harmony feature [±P], or else occur within the domain of one (and only one) such feature.

(51) might at first sight seem somewhat stronger than necessary: (51) requires EACH vowel to meet one of the two conditions of (51), while the argument that led us to introduce it was based upon the observation that each lexical root must contain at least one harmony feature. Obviously, this latter condition can be satisfied by requiring only that AT LEAST one vowel in the root meet either case of (51). It is possible that a root might meet this weaker condition while not meeting the stronger condition.

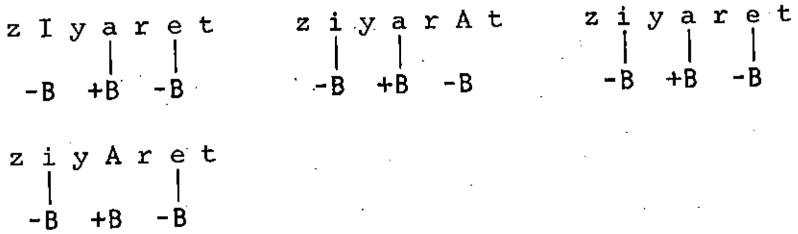
The considerations leading us to choose the stronger form involve roots such as the proper noun *Istanbul* [ɨstanbul] or [istanbul], which is exceptional in the second, more conservative pronunciation with regard to backness harmony in Turkish. There are (among several others) the following two ways of representing this latter pronunciation:

(52)

It seems intuitively clear that (52b) is the correct representation. (52a) obscures the fact that there is a domain of backness harmony in in this word involving two syllables. It characterizes the word as a FRONT root which happens to have an idiosyncratically marked back vowel in medial position. (52b), on the other hand, characterizes the word as a BACK root with an idiosyncratically marked front vowel, and clearly displays the backness domain. If this choice is correct (and I will offer an argument in favor of it, just below), then we have motivation for the stronger of the two suggested interpretations of (51), since this interpretation, alone, selects (52b) as the unique entry for *Istanbul*.

(51), in the strong interpretation, therefore provides one principle for selecting among alternative possible lexical entries for given forms. Another procedure, involving a suggested measure of simplicity, was suggested earlier. Let us now consider taking (45) as our evaluation measure. According to this, that entry (or entries) which (all else being equal) contains the fewer UNPREDICTABLY BOUND features will be selected as the lexical representation. According to this principle, for instance, the correct representation of *ziyaret* must be (50), rather than any of the following forms (the roundness features are disregarded here):

(53)

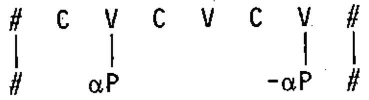


Similarly, (49) is the simplest lexical representation for the form pɪrạko.

The hypothesis underlying this rather elaborate set of principles is that each lexical association of a feature adds to the complexity, or markedness, of the form in question. The underlying principle of vowel harmony is that roots are categorized in terms of certain phonetic features; these features automatically extend to all vowels occurring within the word built upon that root. Now if, as was suggested in Chomsky and Halle (1968), features are to be understood as assigning certain entities (segments, morphemes, boundaries, nodes, etc.) to specified categories -- which may be syntactic, semantic, morphological, or phonetic -- then the features involved in vowel harmony may be (together with the feature category NASAL) unique among nontonal phonetic features, in that they categorize morphemes in the same way that, for instance, morphological features do. In a vowel harmony language, in the ideal case, each lexical morpheme is assigned not only to a set of morphological classes, but to a PHONETIC class, which determines, in part, the quality of its vowels.

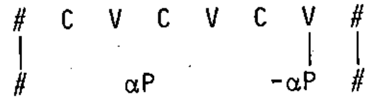
Given this general principle, each exception -- each vowel whose quality must be individually learned, and cannot be deduced from a general regularity of the language -- imposes a memory burden upon the speaker. In cases of imperfect learning (due, for instance, to the relative rarity of an item), or of carelessness, one might expect that precisely these special vowel markings might be lost, causing the root to regularize. Similarly, in cases when we find two variants of a given form, one regular in regard to harmony and the other exceptional, we might expect, all else being equal, that the regular form will be missing a lexical binding found in the other, and will thus represent a simplification. Thus we find, for instance, that the innovative pronunciation of *istanbul* is [ɨstanbul]. This latter, regular form differs from the irregular form in that it contains no idiosyncratic binding (compare (52b), above).

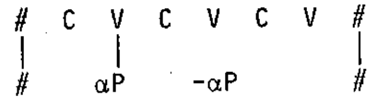
5.3. We have argued that the strong interpretation of (51) receives some support from our general view of lexical representation. There is, however, another, even more compelling reason arguing in favor of this interpretation, which arises from the formal need for unambiguous representations. We have argued that representations must be unambiguous at all levels of derivation, in the sense that they are always uniquely interpretable. We must not allow representations to arise which are subject to multiple interpretations, unless, of course, this happens to be the result we want in some given case. We must therefore be able to exclude lexical entries such as the following, in which we find an ungoverned domain:

(54)


Given such a representation, there is no nonarbitrary way of determining whether the central vowel is to become associated with αP or with -αP.

Now, it is true that for any representation of the form (54) there is always a simpler representation of the form (55) or (56):

(55)


(56)


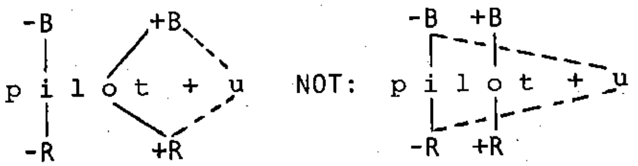
These two representations correspond to distinct surface forms. The evaluation metric (45) will always designate each of these as formally simpler than (54). However, it must be recalled that (46) is not a LEGISLATIVE principle, in the manner of a morpheme structure condition; it is rather an EVALUATIVE principle which assigns a measure of complexity to any representation with which it is presented. It does not, therefore, have the power of REJECTING an entry containing some measure of redundancy. It has the effect of assigning relative indices of complexity to different, descriptively equivalent grammars, and it is by virtue of this property that we can formulate the hypothesis that the language learner will select the simplest grammar compatible with the data, among the various alternatives that are open to him. If, on the other hand, (45) were to be regarded as legislative in function, this hypothesis would not be open to independent empirical verification, but would rather be presupposed to be correct by the theory itself. Consequently, (45) cannot be used to exclude representations such as (54), and to achieve this result we must accept the strong version of (51).

5.4. If we have spent some time arguing for the correctness of (51) in its strong interpretation, it is because we have wanted to show that this principle, the only "extra device" required by this theory of lexical structure, is not arbitrary but can be justified on two independent grounds. If we turn, now, to the advantages which follow from this decision, we can see that they far outweigh whatever extra complexity one might want to attribute to a theory containing such a general principle.

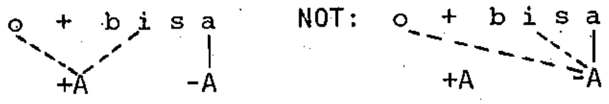
We recall from Chapter 1 that the existence of exceptional lexical roots presented considerable embarrassment to linear attempts (e.g. Lightner 1965) to define vowel harmony in terms of a single "root marker". It was necessary to account for the fact that only the INITIAL and FINAL vowels in such roots determine harmony (in prefixes and suffixes, respectively); but any natural way of doing this increased the difficulty of describing the REGULAR cases of root harmony. Some linguists therefore proposed to introduce SEPARATE statements for root harmony and affix harmony, with separate sets of exceptions to each. However, whatever regularities there were to be found in roots could not be captured in this approach: a root was categorically either regular, or exceptional.

These problems all receive a natural solution within the present framework. No further conditions or principles need to be introduced; the well-formedness condition, as described earlier, applies both within the root and across affixes, providing a correct account of vowel harmony. The possibility of roots that are subject to different harmony constraints vanishes: thus the "mixed" Akan roots bisa, pạtiri are governed by the same principle (the well-formedness condition) as are the fully inflected words in which they occur, and we are not faced with a problem of explaining why *i* fails to assimilate to *a*. The fact that prefixes agree with the leftmost root vowel, and suffixes with the rightmost root vowel as characterized in the principle of root control (Chapter 2, (3)), follows as a consequence of the well-formedness condition, together with Priority Clause A (32):

(57)



(58)



A further, and unforeseen, consequence of our theory is that it has proven capable of describing subregularities within irregular roots, evaluating their relative complexity in an intuitively natural way. Finally, we have been able to dispense with the entire apparatus of rule features and rule context features that have consistently been a necessary element in linear analysis.

6. Before we can claim to have satisfied the set of formal requirements that we placed upon an autosegmental approach to prosodic phonology (see (23) earlier), we must turn to one remaining area of indeterminacy in our theory.

Let us consider rounding harmony in Turkish, and in particular the harmonic behavior of the present tense suffix -(*I*)*yor*. This suffix is not quite regular in structure: its second vowel does not alternate, and therefore (since Turkish has no neutral vowels) is represented as lexically bound to the features [+back] and [+round]. This vowel is furthermore unusual in that nonhigh vowels in suffixes are elsewhere always nonround. The initial vowel *I* of this suffix, on the other hand, is fully regular, and is realized as *i*, *u*, *ɨ* or *ü* depending on the nature of the preceding vowel (see (59a)). As (59b) and (59c) show, the opaque vowel *o* determines the harmonic category of vowels in a following suffix:

(59) a. / *bɨrak + Iyor* / → *bɨrakɨyor*

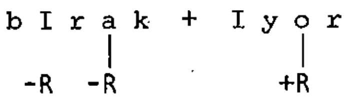
b. / *gid + Iyor + Im* / → *gidiyorum*

c. / *ağɨr + lEş + Iyor + mIş* / → *ağɨrlaşɨyormuş*

(It will be observed that the dialect in question is not the dialect exhibiting Palatal Umlaut, discussed in Chapter 2 (Lees 1967); it is rather standard literary Turkish as described in most textbooks.)

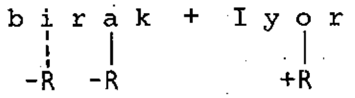
Let us consider the underlying representation of (59a). Since nonhigh, noninitial vowels are redundantly nonround (and therefore opaque), the second root vowel will be bound to the feature [-round]; thus the representation will be:

(60)



By Priority Clause A of the well-formedness condition, the leftmost (unbound) occurrence of -R is associated first with the sole vowel occurring in its domain:

(61)



Now, however, we must add an association line binding /*I*/ to one of the two available segments -R or +R. Which one do we choose?

Either of two principles would give the correct result in this case. First we could propose calling for the LEFTMOST of two available segments to be chosen in such cases. An alternative proposal might be that we select whichever segment belongs to the root; it will never be the case that BOTH segments belong to the root, since configurations of this type cannot arise within roots (cf. the discussion of (51)). However, this proposal lacks sufficient generality, as we can see from a consideration of (59c), in which NEITHER of the available segments belongs to the root in the problematical configuration:

$$(62)\quad \begin{array}{cccccccccccccccccc} A & g & I & r & + & l & e & \text{ş} & + & I & y & o & r & + & m & I & \text{ş} \\ & & & & & & | & & & & & | & & & & & \\ & & -R & & & & -R & & & & & +R & & & & & \end{array}$$

Here, the nonhigh vowel of the first suffix *-lEş* must be lexically bound, as before, due to the general morpheme structure condition prohibiting round nonhigh vowels noninitially. Since neither of the opaque vowels flanking the vowel *I* of the second suffix belong to the root, we must look for a further principle.

(61) and (62) present instances of a more general principle of root control, stated as (3) in Chapter 2 and restated below:

> (63) All nonopaque vowels in a domain agree with the closest occurrence of a harmony-characterizing feature P such that if the domain contains prefixes (resp., suffixes), P is not to its left (resp., right).

Given representations such as (61) and (62), (63) can be interpreted in a straightforward way. In both of these cases, the leftmost segment must be chosen. Let us reformulate (63) in such a way that it does not require separate reference to prefixes and suffixes, but only to the category "root":

(64) Priority clause B (Root Control)

Given the configuration:

$$\begin{array}{ccccc} X_1 & V & \sigma & V & X_2 \\ & | & & | & \\ & P_1 & & P_2 & \end{array}$$

all vowels occurring in the domain σ are bound to that P_j such that $X_j = \ldots$ [+root] ...

With Priority Clause B in the theory, we have a unique solution to the problem presented by affix vowels which are, so to speak, "trapped" in ungoverned domains, as in (62).[14]

(64) is a component of the well-formedness condition on representations for vowel harmony, and (like the other components, such as Priority Clause A (32)) applies whenever defined throughout the course of a derivation. A LINEAR approach to vowel harmony would be committed to building (64) in some way into the statement of each vowel harmony "rule". The difficulties inherent in this approach (mirror image rule application, cyclic application with special conventions, etc.) have been explored in Chapter 2. (64), far from being an otherwise unnecessary artifact of a nonlinear approach, is in fact far less complex than the equivalent set of conditions that would have to be placed upon rule application in a linear approach; and it is consistent with a more specific view of the phonological organization of human languages.

7. Let us now consider, within the framework developed above, the problem posed by the Palatal Umlaut examples in Turkish discussed earlier in Chapter 2, section 4. In particular, let us consider the set of forms which is repeated below:

(65) a. / *okI-mIş* / → *oku-mɨş*

b. / *üşI-yIş* / → *üşi-yiş*

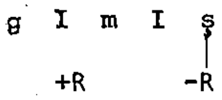
c. / *gümIş-tIr* / → *gümiş-tir*

d. / *ütI-yI* / → *üti-yi*

e. / *dur-IyIm* / → *dur-ɨyɨm*

These forms can be derived in a natural way within the present framework. Let us hypothesize that the Palatal Umlaut dialect differs from the more familiar dialects in the fact that its palatal consonants are inherently (lexically) bound to the segment [-round] on the autosegmental level along which rounding is specified. In other words, let us treat palatal consonants as opaque segments in the same sense that we have treated the low vowel *a* of Akan as opaque. The presence of these consonants will explain the failure of roundness to propagate from the root to the high suffix vowels. We thus have lexical representations like the following:

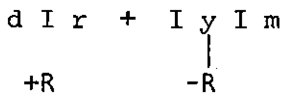
(66)



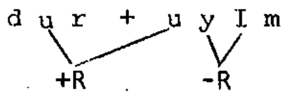
Palatal Umlaut may now be stated, formally, as a rule which spreads the autosegmentally represented segment [-R] from the palatal consonant to the first vowel to its left (provided that vowel is not the first vowel in a polysyllabic root). As this is a phonological rule, it applies after the application of the Well-formedness Condition.

The form *dur-ɨyɨm* will thus be derived as follows:

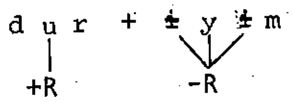
(67) i. the underlying representation is:



ii. by the Well-formedness Condition this becomes:

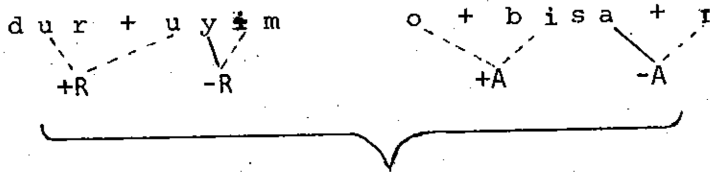


iii. by Palatal Umlaut this becomes:

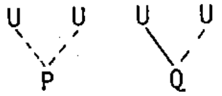


Under this account the "ordering paradoxes" that arise under standard treatments disappear. Palatal consonants, in dialects that have the Palatal Umlaut rule, interrupt the rightward propagation of vowel harmony simply because they are opaque: i.e., lexically associated with an autosegment that governs the domain to its right. In formal terms, the explanation for Palatal Umlaut is identical to the explanation given earlier for mixed vowel words in Akan such as o-bisa-ɪ, as the following chart shows:

(68)



instances of the schema:



We have thus achieved an account of two puzzling and apparently diverse linguistic phenomena, Palatal Umlaut in Turkish and bidirectional harmony in Akan, in terms of a unified set of theoretical principles which are independently motivated in a different descriptive domain, that of tone. In doing so we have had to introduce only one new theoretical concept, that of the opaque segment; and this concept is one that is suggested by the logic of the theoretical framework itself.[15]

8. The above sections have proposed a set of universal phonological principles governing the properties of vowel harmony. Our strategy, as presented in the introduction to this chapter, has been to design a theory that will account in the simplest and most highly-motivated way for the valid generalizations that can be formulated concerning the recurrent properties of vowel harmony. We have been particularly concerned with the property of "root control" as this was characterized in Chapter 2. It has been shown that this property need not be stipulated in an ad hoc fashion within the theory, but follows from the general principles of autosegmental phonology as this has been formulated for the treatment of problems of tonal phonology. It can further be shown that other recurrent properties of vowel harmony follow from the theory proposed here.[16]

If the principles proposed here continue to prove adequate as we look into further aspects of vowel harmony systems, it appears that vowel harmony processes are properly to be viewed as functions of lexical representations rather than of phonological rules, and as such can be extracted from the grammars of particular languages and placed among the general conventions that govern phonological representation in all languages. Thus, what is common to vowel harmony systems in widely separated languages follows from the principles of general phonological theory, and what is idiosyncratic to them follows from individual differences in lexical representations and rule systems.

To summarize our theoretical results, the study of vowel harmony appears to reflect favorably upon the general validity of autosegmental phonology as a model of "prosodic" phonology. In order to incorporate vowel harmony into such a general theory however, two modifications in earlier versions of the theory must be admitted. First, the theory must allow "opaque segments": segments which have underlying (lexical) attachments to autosegmentally-specified features. Secondly, the notion of well-formedness must be supplemented with the "Priority Clauses" (32) and (64), the first of which is general in validity and the second of which (if it proves to be necessary -- cf. note 14) might prove to be restricted to vowel harmony systems. Otherwise, the notion of well-formedness can be maintained without modification. On the basis of these results, it would appear that the autosegmental framework developed here offers a satisfactory (and desirable) account of vowel harmony capturing our pretheoretic generalizations in a simple and consistent way.

NOTES TO CHAPTER 3

[1] See in particular Goldsmith (1974a, 1974b, 1975, 1976a, 1976b) and Haraguchi (1975).

[2] For example, in Welmers (1962) certain of the insights underlying the autosegmental treatment of tone are clearly formulated. In this paper, Welmers disputes the assumption that "tonemes ... can be assigned mechanically to each vowel or syllabic nasal with a correspondence of one tone to one syllable and one syllable to one tone." Rather, he argues, the word (in Welmers' terms, the unit bounded by "open transitions") is the domain over which distributional statements are to be made: "tonemes must be analyzed in terms of segments between two open transitions. Such a segment often constitutes the domain of a single toneme, but it may contain a sequence of two or three tonemes, or occasionally four" (85). Such descriptions were totally incompatible with the ideas about phonological representation current at that time, or for the most part at present. Within generative phonology, important contributions have been made by Williams (1971) and Leben (1973), whose work may be taken as the immediate precursor of autosegmental phonology as this has been characterized by Goldsmith.

[3] Alternatively, the requirements of the Well-formedness Condition could be satisfied by connecting H to 3. It appears that in such cases, reassociation always involves the vowel which was analyzed as the DETERMINANT of the rule whose application resulted in the original ill-formedness.

[4] As far as I know, the exceptions involve rules of allomorphy only.

[5] It is to be noted that the relation of nondistinctness is not equivalent to the relation of identity. The latter is a transitive relation, while the former is not. Thus we cannot say that (g) is IDENTICAL to both (f) and (h), since this would imply (falsely) that (f) and (h) are identical.

[6] As far as the present argument is concerned, it may be assumed that rules (13i-iii) apply either simultaneously, or in the order given.

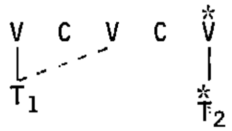
[7] See McCawley (1968, 52) for a similar position, attributed to Halle.

[8] A somewhat less general characterization of the notion SEGMENT is given by Mayerthaler: "diejenigen Einheiten, die man durch maximale segmentation (maximal segmentiert is z. B. L/o/g/i/k / *Logik*) eines Wortes erhält, heissen *Segmente*" (Mayerthaler 1974, 6). [the units which one obtains through the maximal segmentation (for example, L/o/g/i/k / *Logik* is maximally segmented) of a word are called SEGMENTS.]

[9] These analyses would form a segmentation only if the category P is identified as "sets of feature bundles".

[10] The following representation has been simplified for the sake of exposition. In particular, it is lacking flanking brackets (see (27) below, in which they are present), and internal brackets around the root fItI. Brackets, however, are irrelevant for the various rules and processes which determine the set of associations between levels, and will generally be ignored here.

[11] Goldsmith has elsewhere (1976a) suggested a further priority clause, in terms of which an UNSTARRED segment has precedence over a STARRED segment. This principle does not generalize to examples such as (31) in which there is no starred segment. On the other hand, the principle suggested here does not generalize to configurations such as the following:



in which T_1 takes precedence over T_2. Thus, both principles are needed.

[12] The symbol ">" is used here to indicate the result of the application of CONVENTIONS, as opposed to rules.

[13] There is in fact a formal problem in this derivation. The MS rule must be formulated in such a way as to insert the autosegment [-A] to the RIGHT of the autosegment [+A] in order to achieve the correct result; see the following discussion.

[14] The data considered here do not discriminate between principle (64) and the first of the principles considered: that the LEFTMOST autosegment has priority in cases such as (61) or (62). The choice among these alternatives will depend upon further investigation of prefixal vowel harmony systems.

[15] The account of Palatal Umlaut given here is based upon that given in Clements (1974).

[16] [For some suggestions, see Clements (1977) -- GNC]

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