

Vowel harmony

The phenomenon of vowel harmony involves several of the central issues with which we are concerned in this book: (strict) cyclicity, the relation between morpheme structure, phonotactics, and phonological processes, and the problem of abstractness. Particularly interesting in this regard is the functioning of vowel harmony in asymmetrical vowel systems, which contain unpaired vowels, either "neutral" or "opaque." Their proper treatment will be the focus of our investigation.

Among the available approaches to vowel harmony, the one which comes closest to explaining its cross-linguistic properties, and which permits a treatment compatible with the theory of cyclic phonology, is the autosegmental approach elaborated by Clements (1977, 1980). Still, when it is applied to systems with neutral vowels, some weaknesses at the explanatory and even at the purely descriptive level become apparent. I shall suggest a slightly modified version of autosegmental theory which appears to me to succeed in overcoming them.

I shall proceed by analyzing in turn a number of vowel harmony systems which each shed light on some aspect of the problem. The first case to be discussed is Finnish, where a segmental treatment will be compared to a standard autosegmental treatment and this in turn to a treatment in the modified autosegmental framework that I wish to propose.

1. Finnish. The data and the essential generalizations which any treatment of Finnish vowel harmony must address itself to have been presented in previous studies (Kiparsky 1973, Campbell 1977). A more detailed discussion of the system from a historical point of view will be presented in Ch. 6 below.

Finnish has eight vowels, which combine with themselves into geminate (long) vowels and with each other into 17 diphthongs. The feature composition of the vowels is shown in (1):

Neutral vowels are $\begin{bmatrix} -low \\ -rd \end{bmatrix}$

(1)		u	o	a	y	ö	ä	i	e
	back	+	+	+	-	-	-	-	-
	round	+	+	-	+	+	-	-	-
	high	+	-	-	+	-	-	+	-
	low	-	-	+	-	-	+	-	-

The basic vowel harmony constraint is stated in (2):

(2) Non-neutral front and back vowels do not co-occur in words.

This is a constraint on stems (3a) and on combinations of stems and suffixes (3b):

(3) (a)	makkara	'sausage'
	väkkärä	'pinwheel'
	palttina	'linen cloth'
	värttinä	'spinning wheel'
	kaura	'oats'
	käyrä	'curve'
	luo	'creates'
	lyö	'hits'

(b)	palttina + lla + ni + han	'with my linen cloth, as you know'
	värttinä + llä + ni + hän	'with my spinning wheel, as you know'
	luo + da + kse + ni + ko	'for me to create?'
	lyö + dä + kse + ni + kö	'for me to hit?'

Unassimilated loans may violate (2) inside stems:

(4)	tyranni	'tyrant'
	marttyyri	'martyr'

Endings are taken as having the restricted 5-vowel subsystem a, o, u, i, e.
The Harmony rule itself is statable as

$$(10) \quad [+ \text{back}] \rightarrow [\approx \text{back}] / [\approx \text{back}] \left(C_0 \begin{bmatrix} V \\ -\text{round} \\ -\text{low} \end{bmatrix} C_0 \right) + C_{0-}$$

The full complexity of this formulation is necessary to secure the correct output with neutral vowels. The input vowels must be specified as [+back] in order to prevent suffixal i and e from being backed by Harmony. The structural change must be stated as [≈back] rather than [-back] so that only the longest expansion will apply by disjunctive order. To see this consider a word with a back vowel followed by a neutral vowel, e.g. pari 'pair'. In pari+ko 'a pair?', the rule must (vacuously) back the suffixal a in the context of the initial syllable, with i analyzed in the parenthesized expression, and the shorter expansions of the rule are then blocked by the conventions of disjunctive ordering. If harmony is simply taken as a fronting process, it would wrongly give pari+na → *pa^hri^hna^h, like pi^h+na → pi^hna^h.

In order to account for the data in (7) it is necessary to add a Backing rule which applies in the context after monosyllabic neutral stems. This rule must follow Vowel Harmony since its effect would otherwise be undone.

$$(11) \quad \begin{bmatrix} - \text{round} \\ - \text{low} \\ V \end{bmatrix} \rightarrow [+ \text{back}] / \#C_0 \begin{bmatrix} - \text{round} \\ - \text{low} \\ V \end{bmatrix} C_{0+}$$

- (12) (10) /eI + o/
 (11) /eI + ö/
 /eI + o/

However, some way is required of bringing the vowels to the right of the Backed vowel to agree with it. It cannot be done by Harmony itself because it precedes Backing, for the reason just noted. The same problem arises if Vowel Harmony and Backing apply cyclically. It seems, then, that the segmental solution requires still another rule which adjusts the output of Backing appropriately:

$$(13) \quad \begin{bmatrix} \alpha \text{ round} \\ -\alpha \text{ low} \end{bmatrix} \rightarrow [+back] \begin{bmatrix} \beta \text{ round} \\ -\beta \text{ low} \\ +back \end{bmatrix} (C_0 \begin{bmatrix} -\text{round} \\ -\text{low} \end{bmatrix} C_0)_0 \text{---}$$

Assuming iterative application of the rules, we then have derivations as in (14):

	/pien + uut/	/pien + uut + ta + si + ko/
(14) (10)	pien + yyt	pien + yyt + t ^ä + si + k ^ö
(11)	pien + uyt	pien + uyt + t ^ä + si + k ^ö
(13)	pien + uut	pien + uut + ta + si + ko

Merely internally to Finnish, without even considering the cross-linguistic generalizations that hold for vowel harmony systems, it is already clear that the segmental solution is unacceptable. One objectionable feature of it is the need to exclude the class of neutral vowels in every rule. The class $\begin{bmatrix} -\text{round} \\ -\text{low} \end{bmatrix}$, or its complement, here specifiable as $\begin{bmatrix} \alpha \text{ round} \\ -\alpha \text{ low} \end{bmatrix}$, figures in our rules (8,9,10,11,13) no less than nine times. In addition, the restriction of rule (10) to [+back] also serves to pick out the non-neutral vowels, so as to block suffixal i, e from undergoing Back harmony. This is a clear symptom that the theory is not permitting our analysis to grasp the special character of neutral vowels. Moreover, it is apparent that rule (13) essentially duplicates the effect of the main Vowel Harmony rule (10); yet it cannot be combined with it.

A better solution is available if we adopt Clements' proposal (1977) to extend to vowel harmony the autosegmental theory first introduced by Goldsmith (1976) for tone features. The idea is that the harmonic feature is represented on an autonomous "tier" and is associated with the harmony-bearing elements (vowels) in accordance with a set of universal well-formedness conditions. As a result, the language-particular vowel harmony rules that we found to be irredeemably redundant in the segmental solution can be radically simplified, and indeed largely eliminated. What the grammar has to specify for a vowel harmony system is essentially the appropriate initial representations, from which the association of harmonic features by the universal well-formedness conditions will yield the correct output representations. For Finnish, the grammar specifies that the feature

[Back] is represented on its own tier (is "autosegmentalized") and that it is associated with roots (but not suffixes) in the lexicon.

If we simply were to generalize to harmony the well-formedness conditions formulated by Goldsmith for tonal systems, we would obtain (15):

- (15) a. All vowels are associated with at least one harmony feature. ✓
- b. All harmony features are associated with at least one vowel.
- c. Association lines do not cross.

The following convention can be adopted for cases where violations of (a-c) above arise in a derivation, for example by the operation of a phonological rule:

- (15) d. Association lines which violate WFC's (a-c) and features which cannot be associated are deleted. } ?

Hence, when a harmonic feature becomes associated with a vowel, any other harmonic features are automatically dissociated from it by virtue of WFC (15d). That is one effect which we shall wish to retain in our revised version of autosegmental theory.

Given this framework, which we may for convenience refer to as the Standard Autosegmental Theory (SAT), the vowel system of Finnish contains five harmony-bearing vowels A, E, O, I, E and the autosegmental element ± B, which is assigned as a distinctive feature to each stem but not to affixes. It is still necessary to include in the phonology a rule which fronts i and e:

$$(17) \quad \begin{bmatrix} -\text{round} \\ -\text{low} \end{bmatrix} \rightarrow \begin{bmatrix} -\text{B} \\ | \end{bmatrix}$$

$$(18) \quad \begin{array}{c} +\text{B} \\ / \quad | \quad \backslash \\ \text{pari} \quad + \quad \text{na} \quad + \quad \text{kin} \end{array} \rightarrow \begin{array}{c} +\text{B} \quad -\text{B} \quad +\text{B} \quad -\text{B} \\ / \quad / \quad | \quad / \\ \text{pari} \quad + \quad \text{na} \quad + \quad \text{kin} \end{array}$$

(parinakin, not *parinakin)

Secondly, it is necessary to add a MS condition to the effect that stems containing only i and e may not be associated with +B.

$$(19) \quad \begin{array}{c} +\text{B} \\ | \\ *(C_o \begin{bmatrix} -\text{round} \\ -\text{low} \end{bmatrix}_o C_o)_o \end{array}$$

This is to block any derivation like pii+na → *piina while still allowing "mixed" stems like piina to exist.

A Backing rule is still necessary but it can now be simplified to a form

$$(20) \quad V \rightarrow \begin{array}{c} +\text{B} \\ | \\ V \end{array} / \# C_o \begin{bmatrix} -\text{round} \\ -\text{low} \\ V \end{bmatrix}_o C_o + _$$

in which it is also applicable to i and e, because (17) then fronts these vowels again anyway.

The co-occurrence restrictions on vowels can also be simplified. The constraint that front and back non-neutral vowels cannot occur together in native lexical entries can be stated in the form (21):

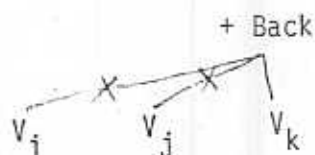
(21) Every non-compound word contains at most one harmonic feature.

This autosegmental solution is obviously an improvement over the segmental solution. It eliminates the worst redundancies in the latter and simplifies several aspects of the system. Yet it is open to the criticism that it treats as accidental several properties of Finnish which are found very generally in vowel harmony systems. Its weakness is therefore more apparent from a typological perspective. I shall review the properties in question and propose a revision of the autosegmental format which predicts them without sacrificing any of the other advantages of the theory.

1. Vowel harmony is structure-preserving. It is true of Finnish and of all vowel harmony systems known to me that the vowel harmony process does not create any new segment types. The set of vowels that appears in the output of the vowel harmony process is identical to the set of vowels that appears in the input. From the viewpoint of the SAT, this "structure preserving" property is quite unexpected. As we have seen, the exclusion of distinctively back counterparts of i and e in the lexicon (the type *pii+na) requires a MS condition limiting [+Back] to stems containing at least one non-neutral vowel. And the exclusion of phonetically back counterparts of i and e in the output requires a rule which fronts i and e (rule 17). That is, the theory claims that Finnish would be a simpler language if rule (17) were dropped, whereas what the correct theory must claim is that such a form of Finnish would be an impossible language.

Above we noted that the Backing rule (20) applies only after mono-syllabic neutral stems (pien-uus 'small size' vs. piene+mm+yys 'smaller size', see (7)). This rather mysterious restriction can now be generalized along similar lines. It is paralleled by the fact that monomorphemic stems of Finnish containing neutral vowels can end in back or front vowels if disyllabic (e.g. ilma 'air', vs. silmä 'eye') but (with rare exceptions) only in front vowels if polysyllabic (e.g. ketterä 'agile', rettelö 'brawl', kipinä 'spark', hedelmä 'fruit', himmeä 'dim').

(22) *



where V_i, V_j are $\begin{bmatrix} -\text{low} \\ -\text{round} \end{bmatrix}$

State must of filter should not require variable

This is the same condition that we found on the Backing rule, and yet we so far lack a means of relating its static, morpheme-internal and dynamic, derivational manifestations. We merely have yet another unexplained appearance of the class of neutral vowels in the phonological rules of Finnish.

2. The phonetic and harmonic value of neutral vowels is predictable. It is well known (cf. Aoki 196) that not any arbitrary vowels function as neutral. Neutral vowels show a predictable value of the harmonic feature, namely [- Back], [- Round], [- ATR], and [- Nasal], to cite the four most important cases.

Moreover, it is surely not accidental that the neutral vowels trigger front harmony when alone (see 6). Even the segmental analysis manages, (albeit in a much too complicated way) to attribute their harmonic value to the fact that they are front vowels. In this respect the SAT analysis actually is a step backwards.

3. Neutral vowels are predictably transparent. The SAT analysis will have to contain both a Backing rule (20) and a Fronting rule (17). As we have seen, the autosegmental feature [\pm Back] introduced by (20) must spread to the right, while the autosegmental feature [- Back] introduced by (17) must not spread to the right. Even if one of these is assumed to happen by virtue of a general convention, the other must be stated in the grammar. But it is evident that the difference simply follows from the fact that Backing (20) applies to non-neutral vowels while Fronting (17) applies to neutral vowels. We therefore conclude that SAT fails to account for the predictable transparency of neutral vowels.

Observations 1-3 suggest the following modifications of the theory.

The behavior of neutral vowels is best modeled by taking them to be unassociated with harmonic features. Like consonants, they function as non-harmony-bearing elements, which are "skipped over" when the harmonic features are associated with vowels:

(23) $\begin{array}{c} B \\ | \\ \text{parI} + \text{nA} + \text{sI} + \text{kO} \end{array} \rightarrow \begin{array}{c} B \\ / \quad \backslash \quad \backslash \quad \backslash \\ \text{parI} + \text{na} + \text{sI} + \text{ko} \end{array} = \underline{\text{parinasiko}} \text{ 'as your partner?}'$

If neutral vowels are unassociated with the autosegmental feature, we require some principle by which they are assigned the correct phonetic representation. It may be assumed to be the same which assigns the predictable value of the harmony feature to consonants. Such a principle is also required for non-neutral vowels, since they now will remain unassociated with the harmonic feature in suffixes of stems containing only neutral vowels (e.g. Finnish /vIE + kO/ (viekö) 'does (he) bring?').

The structure-preserving property indicates that vowel harmony is controlled by language-particular well-formedness conditions which hold for underlying and surface representations, as well as for all intermediate stages in the phonological derivation. The segment structure condition that excludes \dot{i} , \dot{e} , and the sequential constraints (21), (22), are examples of such overriding well-formedness conditions. If we take the strongest position and claim that all language-particular constraints on the spreading of harmony features are governed by well-formedness conditions, a number of interesting empirical consequences follow.

Let us assume that every phonological feature (or at least every harmonic feature) has a designated marked value. The notion of markedness used here is context-independent

and must be distinguished from the richer concept elaborated in Chomsky and Halle (1968, Ch.9) and Kean (1976), although it is not necessarily incompatible with it. It is closer to Praguian markedness theory in taking the marked value of a feature to denote a positively specified

property and its unmarked value as the absence of that property. Thus, the marked values of the features Back, Round, Nasal, and ATR is the "+" value, denoting respectively tongue retraction, lip rounding, nasality and tongue root advancing, while the "-" value specifies, not some other properties, but simply the absence of these same properties. In this way we automatically have the desired interpretation of unassociated segments. A vowel unspecified for F is equated to a vowel that is not-F, (\bar{F}), i.e. it is interpreted as having the "unmarked" value of F:

$$(24) \quad V = \bar{F} \underset{V}{|}$$

From this we predict at once that neutral vowels in Finnish are realized as front rather than back, and more generally that vowels unspecified for a feature F are realized with the unmarked value \bar{F} . At the same time, the fact that words with neutral vowels take front-vowel suffixes follows directly from the same principle. The "derivation" of pii+nä is reduced to nothing, the phonetic representation being the same as the underlying representation:

This is important

$$(25) \quad pII + nA \quad (= \underline{pii+nä})$$

where capitals denote segments unspecified for the harmonic feature.

Since \bar{i} , \bar{u} no longer figure in derivations, we have also eliminated the Fronting rule (17) and the problems that go with it. The rightward spread of the feature inserted by the Backing rule (see 14) now can take place by a general convention:

$$(26) \quad pIEn + UUt + tA \rightarrow pIEn + \overset{B}{\swarrow} \underset{\searrow}{uut} + ta \quad (= \underline{pienuutta})$$

An immediate objection must be faced. If we introduce unspecified feature values into phonological representations, then what about the well-known problems which originally caused them to be excluded in phonological theory? It was noted by Lightner (1963) and Stanley (1967) that if rules can apply to matrices containing unspecified feature values, then they can make non-distinct feature matrices distinct under any possible interpretive conventions. Suppose that we have the three feature matrices in (27):

$$(27) \quad (i) \begin{bmatrix} 0 & A \\ - & B \\ - & C \end{bmatrix} \quad (ii) \begin{bmatrix} + & A \\ - & B \\ - & C \end{bmatrix} \quad (iii) \begin{bmatrix} - & A \\ - & B \\ - & C \end{bmatrix}$$

Here (i) is nondistinct from (ii) and from (iii). Now we apply rules (27 i, ii) to (26).

$$(28) \quad (i) \quad [+ A] \rightarrow [+ B] \\ (ii) \quad [- A] \rightarrow [+ C]$$

We may either assume that a rule applying to a specified feature value [\times F] applies to unspecified inputs [0 F], or that it does not. Under the former assumption (the "distinctness convention"), applying (28) to (27) gives (29a), under the latter assumption (the "submatrix convention") it gives (29b):

$$(29) \quad (a) \text{ By the distinctness convention: } (i) \begin{bmatrix} 0 & A \\ + & B \\ + & C \end{bmatrix} \quad (ii) \begin{bmatrix} + & A \\ + & B \\ - & C \end{bmatrix} \quad (iii) \begin{bmatrix} - & A \\ - & B \\ + & C \end{bmatrix} \\ (b) \text{ By the submatrix convention: } (i) \begin{bmatrix} 0 & A \\ - & B \\ - & C \end{bmatrix} \quad (ii) \begin{bmatrix} + & A \\ + & B \\ - & C \end{bmatrix} \quad (iii) \begin{bmatrix} - & A \\ - & B \\ + & C \end{bmatrix}$$

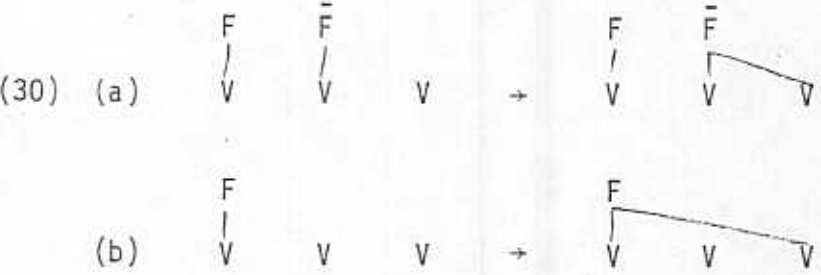
In both outputs, (i) is distinct from (ii) and from (iii), although it was nondistinct from them in the input (27). The "unspecified" feature is then de facto functioning as a third feature value, which is not what was desired.

Contrary to what has been assumed, this does not show that phonological rules cannot be permitted to apply to representations containing unspecified feature values. It does show that the unspecified value cannot be distinct from both specified values. If the unspecified value is distinct from one specified value and nondistinct from the other, the above paradox does not arise. And the "logic of markedness" provides for exactly that. The structural analyses of rules must be restricted to two specifications, namely whether a segment is, or is not, specified as F. That is, we allow no distinction to be made in the environments of rules between a V that is unspecified for F and a V that is specified as having the unmarked value of F.



There are two obvious ways of achieving this reduction in expressive power. The first is to stipulate the equivalence (24) as a convention for interpreting phonological rules. Then we would still allow three kinds of vowels to appear in phonological representations, namely the types

$\overset{F}{V}$, $\overset{\bar{F}}{V}$, and V. Although no rule of the grammar could distinguish between the latter two, they would still function differently in derivations by virtue of the universal conventions of autosegmental phonology. The specification \bar{F} would function as an autosegmental element on a par with F (30a), while unspecified vowels would be transparent (30b):



This is essentially the revision in the Boenigge paper

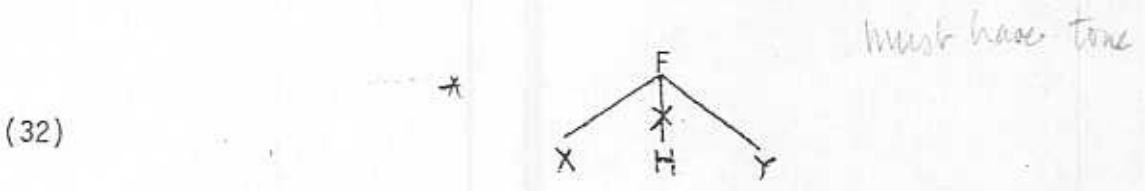
This would be one natural way of dealing with the distinction between opaque and neutral vowels. Thus, the second vowel is opaque in (30a) and neutral in (30b).

A second way, simpler and still more restrictive, is to eliminate the specification \bar{F} from phonological representations altogether. There will thus be only two harmonic classes of vowels, those associated with the marked feature value, \bar{V} , and those not associated with it, V . I shall attempt to work out the treatment of vowel harmony in terms of this version of the theory. It will now be necessary to deal with the distinction between neutral and opaque vowels in a different way. The overriding language-particular well-formedness conditions that govern vowel harmony may be used for this purpose as follows.

We have seen that neutral segments N are those segments which are subject to a well-formedness condition which prohibits their association with the harmony feature:



Suppose we now define the class of harmonic segments H as those segments which must be associated if they are in a harmonic domain. Let us say that they are subject to a well-formedness condition that prohibits them from being "skipped over" in the association of the harmonic feature:



We can now define opaque segments as those which belong to both these classes at the same time. Since they are neutral, they must be left unassociated (31) and since they are harmonic, they may not be skipped if they are in a harmonic domain (32). It follows that these segments cannot be contained in a harmonic domain at all. But this is precisely the criterial property of opaque segments. We therefore arrive at the following classification:

opaque = neutral + must have tone

			non-neutral	opaque	non-harmonic
(33)	WFC (31)		-	+	+
	WFC (32)		+	+	-

Where opaque vowels are not at issue, I shall continue to refer to non-neutral vowels as "harmonic" and non-harmonic vowels as "neutral" for convenience, though both these terms as here defined also include opaque vowels.

Let us refer to the above cluster of assumptions as the Modified Autosegmental Theory (MAT). In what follows I shall explore a number of vowel harmony systems in this framework.

Returning first to Finnish, the facts of vowel harmony can now be accounted for very simply. A well-formedness condition designates the vowels I, E as neutral:

(34) * B
 |
 [-low]
 [-round]

Only non-neutral vowels are harmonic (subject to WFC 32); i.e. Finnish lacks opaque vowels. (We shall see that this is not quite true for foreign words). Finnish is furthermore subject to the syntagmatic well-formedness conditions (35) and (36), which correspond to (21) and (22):

(35) Association is maximal up to the word level.

(36) * [X ^B B where X contains two or more syllables.

*Only Finnish words
appear with
neutral vowels
can harmonize
the rest are
[-B]*

WFC (35) says that Finnish does not have disharmonic stems or words. This condition holds in all the vowel harmony systems I have studied, and I shall provisionally assume that it is universal. Apparent non-maximal association of harmonic features will arise only in observance of language-particular WFC's that systematically prohibit association in certain contexts.

WFC (36) is clearly an idiosyncratic restriction of Finnish. Still, we shall see below that very similar restrictions can be found in other languages.

It can now be seen that all the complications that previously arose in connection with neutral vowels now reduce to the single well-formedness condition (34~~35~~). It accounts directly for the facts which in the segmental analysis as well as in SAT, require, as we saw, repeated mention of the class of neutral vowels $\left[\begin{array}{l} \text{round} \\ -\text{low} \end{array} \right]$, or of its complement:

- (1) The absence of */i/, */e/ in the underlying vowel inventory.
- (2) The co-occurrence of the front vowels i and e with back vowels in stems.
- (3) The operation of Vowel harmony "across" i and e.
- (4) The failure of Vowel Harmony to back i and e.
- (5) The failure of the Backing Rule to back i and e.

The fact that i and e by themselves select front suffixes is now predicted from the fact that they are not associated with [Back] and that unassociated vowels are automatically interpreted as front by (24).

We illustrate the system with some derivations:

17) (a) $\overset{B}{\nearrow} \text{l} \text{uo} + \text{dA} + \text{ksE} + \text{nI} + \text{kO} \rightarrow \text{l} \text{uo} + \text{d} \text{a} + \text{ksE} + \text{nI} + \text{k} \text{o} = \underline{\text{luodakseniko}}$

(b) $\text{l} \text{UO} + \text{dA} + \text{ksE} + \text{nI} + \text{kO} = \underline{\text{lyödäksenikö}}$

(c) $\text{vIE} + \text{dA} + \text{ksE} + \text{nI} + \text{kO} = \underline{\text{viedäksenikö}}$

The Backing Rule is now reduced to its minimal form

(38)
$$V \rightarrow \overset{B}{V} / _] _$$

The WFC (34) correctly blocks the rule from applying to i, e in words like el + in 'organ'. The WFC (35) correctly blocks it from applying to non-neutral front-vowel stems (näk + ö ≠ *näk + o), and the WFC (36) correctly blocks it from applying after polysyllabic neutral-vowel stems (pienemm + yys ≠ *pienemm + uus). The fact that the rule only applies to suffix vowels, which are inherently unspecified for the feature of Backness, and does not change the inherently specified stem vowels, follows from strict cyclicity. (For motivation for the cyclic status of the Backing rule in Finnish see *Kiparsky 1973 and Ch. 6 below*). The only thing, in fact, that must be said in the grammar of Finnish about Backing is that there is such a change and that it applies to vowel-initial suffixes: hence, crucially, no variable after the bracket in (38).

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The MAT discloses an interesting regularity even in the unassimilated foreign vocabulary. The vowels y and ö may be "skipped over" for purposes of suffixal harmony. Thus, there is variation between (39a) and (39b):

(39) (a) $\overset{B}{\text{martt}}\text{yyri} + \text{ko}$ (y treated as non-harmonic)

(b) $\overset{B}{\text{martt}}\text{yri} + \text{kö}$ (y treated as harmonic)

I cannot make this work - mechanically -
it needs to be expanded to be understandable! (for me)

Given the MAT framework sketched out here, y in marttyyri must be a neutral vowel, since otherwise B is not maximally associated and the word violates WFC (35). We thus characterize the exceptional status of such loanwords in the Finnish system by marking their rounded vowels as incapable of association with the autosegment Back, i.e. as subject to WFF (31) (with F = Back). Then association is maximal and the correct vowel sequence is obtained. The variation between (39a) and (39b) can now be seen as depending upon whether the rounded vowel is harmonic or not. In (39a) y is non-harmonic, i.e. not subject to WFC (32), and in (39b) it is harmonic (opaque), i.e. it is subject to that WFC. Such data show that it must be possible to assign vowels to the class of neutral or opaque vowels not only by means of general WFC's such as (34) but also idiosyncratically as in these loanwords.

What we never find is that back vowels are "skipped"; (40a) is obligatory and (40b) is impossible:

- (40)
- (a) $\begin{array}{c} \text{B} \\ \diagdown \quad \diagup \\ \text{tyranni} + \text{ko} = \text{tyranniko} \end{array}$
- (b) *tyranniko

The asymmetry is rigorously explained by MAT because there actually is no way to represent back vowels as neutral (non-harmonic) in this theory. To be neutral they must be unassociated but to be back they must be associated with the harmonic feature [Back]. The fact that there are two alternative treatments of only front vowels corresponds to the fact that the MAT makes available two alternative categorizations only for front vowels. To the left of a back vowel, as in (40), the difference between these two categorizations is undetectable and only one output is derivable.

The crucial feature of the autosegmental approach is that vowel harmony is not a rule but a process governed by well-formedness conditions on phonological representations. This means that vowel harmony cannot be extrinsically ordered in the phonology, but applies as soon as, and however many times, the conditions for its application are met. In conjunction with the theory of integrated morphophonology (Ch.2 above) this implies that vowel harmony must always apply cyclically, that is, at each stage of the morphological derivation. This is because not being a rule, it cannot be ordered in the

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..

post-cyclic component, and moreover in domain harmony systems (35) would be violated in the cyclic stages of the derivation if it were so ordered. Because vowel harmony is universally cyclic and is also a feature-changing process, it cannot apply inside morphemes. This has the further consequence that mixed - harmonic morphemes in non-domain harmony systems are derivable in a straightforward way. The harmonic element is associated in the lexicon to the vowels that bear it and cannot spread to the other vowels of the morpheme, by strict cyclicity.

The vowel harmony systems I have studied can be described, given this framework, largely in terms of general autosegmental principles interacting with the well-formedness conditions which any analysis requires for the structure of simple morphemes in the lexicon. The few language-particular rules required, such as the Finnish Backing rule, are also of a formally restricted type. All of them are rules which insert the harmonic feature. We have found no rules which delete harmonic features. Such rules would be required if there existed vowel harmony processes that neutralize underlying contrasts. As a simplest example, consider a hypothetical language with a three-vowel system a, i, u, where vowel harmony effects the changes

$$(41) \quad \begin{array}{l} i \rightarrow u \quad / \quad u _ \\ u \rightarrow i \quad / \quad i _ \end{array}$$

and a is a neutral or opaque vowel after which an underlying contrast between i and u is manifested:

$$(42) \quad \begin{array}{lll} /a + i/ = a + i & /i + i/ \rightarrow i + i & /u + i/ \rightarrow u + u \\ /a + u/ = a + u & /i + u/ \rightarrow i + i & /u + u/ \rightarrow u + u \end{array}$$

This type of system would have the underlying vowel inventory A, I (specified as [\pm high]) and an autosegment Round. The vowel A is subject to WFC (31) (with F = Round) and, if opaque, also to (32).

Note now that the harmony of $\overset{R}{|}u + I/$ to $\overset{R}{\wedge}u + u$ follows from the ordinary spreading conventions, but the converse case $/I + \overset{R}{|}u/ \rightarrow I + I$ would require

However, this cannot be regarded as a decisive refutation of (44) because it is not clear that a phonological treatment is appropriate for Manchu vowel harmony. As Odden (p. 163-4) shows, there is a virtually equivalent non-phonological diacritic analysis for the same data, in which the vowel alternations are treated essentially as lexically conditioned ablaut phenomena. Odden prefers the phonological analysis summarized in (45), but only on a priori grounds, not on the basis of any empirical argument. Should some principle such as (44) be tenable, the phonological analysis would obviously have to be incorrect.

Another possible system of this general type may have existed in Chumash (Poser MS).

Deletion of inherently specified autosegments would be required if such phenomena as umlaut and other assimilation processes were to be treated autosegmentally. But there is some reason to doubt that they should be so treated. Generally they differ from harmony processes in other ways too. Thus, they are characteristically local, rather than spreading over the whole word like vowel harmony. Moreover, assimilation has much in common with dissimilation, which by definition cannot be treated autosegmentally because there is no spreading feature. Therefore, I assume that a non-autosegmental solution is appropriate here.

a special rule deleting R. Straightforward cases of this type are not known to me. As another hypothetical example, consider a language where vowel harmony operates bidirectionally. Suppose that we have the same vowel system and the pattern (43):

$$(43) \quad \begin{array}{l} /i + i/ \rightarrow (\text{unchanged}) \quad /u + i/ \rightarrow \begin{cases} u + u & \text{in nouns} \\ i + i & \text{in verbs} \end{cases} \\ /i + u/ \rightarrow \begin{cases} i + i & \text{in nouns} \\ u + u & \text{in verbs} \end{cases} \quad /u + u/ \rightarrow (\text{unchanged}) \end{array}$$

Again we would require deletion, operating left-to-right in nouns and right-to-left in verbs. This type of system also does not appear to be documented.

It may therefore be possible to constrain the theory further by the additional condition (44):

(44) No phonological rule may delete a harmonic autosegment.

This, however, would not be a consequence of our theory but a separate stipulation.

*that such
bikunira
change
etc.
p. 152
Odden*

A language with a vowel harmony system requiring deletion of an autosegmental element, in violation of condition (44), may be Manchu, if I have correctly understood the findings of Vago (1973) and Odden (1978). In Manchu there is a suffixal alternation between e and a depending on whether the closest nonhigh stem vowel is front or back. It seems that e and a must both be set up as underlying in suffixes and therefore "the Vowel Harmony rule must change e to a after back vowels and change a to e after front vowels" (Odden 1978, p. 151). Unfortunately, the underlying distinction between e and a in suffixes is not revealed by any systematically neutral type of stem but by apparent exceptions to vowel harmony. Assuming, however, such a distinction, an autosegmental analysis would have to counteract a deletion of the autosegment Back in suffixes. Moreover, according to Odden, the language contains four underlying high vowels i, ɨ, ɯ, u, which are neutralized into two surface high vowels. The pattern apparently is:

$$(45) \quad \begin{array}{cccccccc} i & a & \rightarrow & i & e & i & e & \rightarrow & i & e \\ \dot{i} & a & \rightarrow & \dot{i} & a & \dot{i} & e & \rightarrow & \dot{i} & a \\ \ddot{u} & a & \rightarrow & \ddot{u} & e & \ddot{u} & e & \rightarrow & \ddot{u} & e \\ u & a & \rightarrow & u & a & u & e & \rightarrow & u & a \end{array}$$

2. Hungarian. Hungarian vowel harmony has been discussed extensively and has supplied one of the most straightforward instances of an apparent "absolute neutralization" rule. In the following analysis it will be seen that no such rule exists in Hungarian, given the MAT as proposed here. The important previous treatments known to me are Lotz (1939), Esztergar (1971), Jensen (1972) Vago (1976, 1978) Ringen (1978), Clements (1977) and most recently Vago (1980), on which I primarily depend.

The Hungarian vowel system contains fourteen vowels, seven short and seven long (the latter marked with an acute accent in the orthography, or with two if umlauted). I shall assume the following assignment of features.

(46)		[- Round]	[- Round] Back	[+ Round]	[+ Round] Back
[+ High]		i, <i>i̇</i>		ü, <i>ü̇</i>	u, <i>u̇</i>
[- High, - Low]		<i>ė</i>		ö, <i>ö̇</i>	o, <i>ȯ</i>
[+ Low]		ε e	a, <i>ȧ</i>		

It will be seen that the values of the feature [± Low] are predictable, by a rule to the following effect:

(47)
$$[V \rightarrow [-low] - / \left. \begin{matrix} [+ Round] \\ [+ Long] \end{matrix} \right\} \text{Back}]$$

what does this mean?

This rule operates on the output of certain (cyclic) phonological ~~rules~~ processes, including Vowel Harmony. The proper specification of the values for [x Low] also simplifies the operation of those phonological rules themselves, as we shall see shortly. I assume then that (47) is a cyclic phonological rule. Because it is a non-feature-changing rule it applies also on the first cycle.

Does this presuppose an alphabet?

The basic constraint of Backing Harmony is that, in non-compounded native words,

(48) Rounded front vowels cannot occur with back vowels in the harmonic domain.

A harmonic domain is a noncompounded word; foreign words and certain suffixes may violate (48).

Backing Harmony is reflected in alternations between back and front variants of inflectional and derivational suffixes. The back variants appear after back-vowel stems and the front variants appear after front-vowel stems, as exemplified by the suffixes -nak/-nek 'dative' and -tól/től 'ablative':

(49)	<u>ház</u>	'house'	<u>háznak</u>	<u>háztól</u>
	<u>radír</u>	'eraser'	<u>radírnak</u>	<u>radírtól</u>
	<u>öröm</u>	'joy'	<u>örömgnek</u>	<u>örömtől</u>
	<u>tömeg</u>	'crowd'	<u>tömegnek</u>	<u>tömegtől</u>

This much is similar to Finnish and can be treated in the same way. We again suppose that the feature [Back] is represented autosegmentally. The cooccurrence restriction (48) is mirrored by well-formedness condition (35):

?

For the non-harmonizing, neutral vowels, we require a well-formedness condition that unrounded nonlow vowels cannot be linked to [Back], i.e. that Hungarian has no *ī, *ī̄, *ē, *ē̄ in its vowel inventory. This WFC at the same time makes ī, ī̄, ē harmonically neutral.



Alternating suffixes are underlyingly unspecified for the ^{autosegment} feature Back and may be associated with same value of that feature by the spreading conventions, or, if not so associated, are automatically interpreted as fronted by (24). The vowel inventory of alternating suffixes must now be, according to our theory, obtainable from (46) by eliminating its specifications for the feature Back. The resulting archisegments, which we denote by capitals as before, are the following:

	Underlying	Examples	
(52)	<u>I</u>	Terminative <u>-ig</u>	} no alternations (by WFC 51)
	<u>E</u>	Essive-Formal <u>-ként</u>	
	<u>Á</u>	Dative <u>nek~nak</u> , Adessive, <u>-nél~náł</u>	} front/back alternations
	<u>O</u>	Ablative <u>-tól~től</u>	
	<u>U</u>	Essive-Modal <u>-ul~ül</u>	

The result is correct in that all predicted cases of front-back harmony are instantiated (see examples) and there are no others. The derivation of é from Á involves also raising by rule (47), e.g.

(53) $\text{ör}^{\text{ö}}\text{m} + \text{n}^{\text{á}}\text{ł} \left(= \text{ör}^{\text{ö}}\text{m} + \text{n}^{\text{é}}\text{ł} \right) + (47) \text{ör}^{\text{ö}}\text{m} + \text{n}^{\text{é}}\text{ł}$

Thus the system correctly predicts the existence of suffixes with invariable é (underlying long É) and é alternating with á (underlying long Á).

There are some fifty noun stems and verb roots with only i, í which unexpectedly select back vowel suffixes; also two such roots with é, but none with e:

(54)

<u>híd</u> 'bridge'	<u>híd+nak</u>
<u>cél</u> 'aim'	<u>cél+nak</u>

*Does this mean that the
has the rule (27)
- front
- back*

*e → é
é → É*

These are the cases for which a number of previous analyses have posited abstract underlying back unrounded vowels, along with a rule of "absolute neutralization:"

$$(55) \quad \left[\begin{array}{l} + \text{syllabic} \\ - \text{round} \\ - \text{low} \end{array} \right] \rightarrow [- \text{back}]$$

which applies after vowel harmony, e.g. /híd+nek/ → (V.H.) híd + nak → (55) híd + nak. From our present point of view, it is necessary to assign these stems the feature [Back] in their lexical entry. Because of WFC (51), this "floating" autosegment cannot be associated with the stem vowel. If a non-neutral suffix is added, association to the suffix vowel takes place; otherwise the autosegment must remain unassociated and is deleted by convention.

$$(56) \quad \begin{array}{l} \text{B} \\ \text{a. } \text{híd} + \text{nAk} \quad \rightarrow \quad \text{híd} + \text{nak} \\ \text{B} \end{array}$$

$$\begin{array}{l} \text{B} \\ \text{b. } \text{híd} \quad \rightarrow \quad \text{híd} \end{array}$$

The class of words like híd(+nak) is thereby represented as marked relative to words like szín(+nek). This correctly predicts that new additions to the vocabulary, such as loanwords, will take front suffixes if they contain neutral vowels, e.g. film + nek.

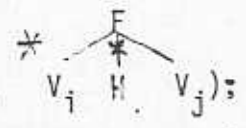
The status of the low vowel e([ɛ]) is different in some respects from that of the other unrounded front vowels i, í, é (Ringen 1978, Vago 1978).

In most respects it functions as a non-neutral vowel. It is the only unrounded front vowel which alternates with a Back counterpart (see 49) in accordance with the usual Hungarian vowel harmony pattern. Moreover, it is the only unrounded front vowel which is never capable of selecting back suffixes on its own. That is, there are only stems like kert, kert + nek 'garden', and none ^{stems with e} analogous to the type híd, híd + nak 'bridge', which occurs with stems containing i, í and (albeit rarely) é. In both these respects, e functions like the other non-neutral front vowels ü, ö etc. However, when e follows back vowels in stems it behaves as a regular non-neutral vowel only in some words (57a). In others it is optionally "skipped over", in the same way as the neutral vowels í, é, (57b) or obligatorily (57c):

- (57) (a) József József + nek
- (b) Ágnes Ágnes + nak, Ágnes + nek
- (c) radír radír + nak

These data show that ^{while} e is ordinarily a non-neutral vowel in Hungarian, in stems where it cooccurs with back vowels, it can be categorized as neutral. It turns out that the variation shown in (57a,b) depends on which type of neutral vowel it is: non-harmonic or opaque.

Recall that we distinguish two intersecting classes of vowels: harmonic vowels H must be associated with the harmony feature if they are in its domain



(i.e. they are subject to WFC (32) of section 1, neutral vowels may not be associated with the harmony feature (i.e. they are

subject to WFC (31) of section 1, ^F opaque vowels are defined as those which are both harmonic and neutral: they may be neither skipped nor left unassociated if they are in a harmonic domain, and therefore they may not be contained in a harmonic domain at all. As before, I use the terms non-neutral and non-harmonic to specifically exclude opaque vowels.

why there are no stems with only e that take back harmony, i.e. that have floating B. It follows from the fact that neutral-vowel stems with floating B (e.g. híd) are exclusively [+ Native] (though a few of them are historically loanwords, e.g. cél 'goal' from German Ziel).

I conclude that the whole range of apparent irregularities connected with the harmony of e in Hungarian is *resolved* by the MAT.

In Hungarian there are some morphemes which are used both as case endings (14a) and as independent stems which themselves take possessive suffixes (60b):

(60)	(a)	<u>ház</u> + <u>tól</u>	'from the house'	(b)	<u>tol</u> + <u>em</u>	'from me'
		<u>fül</u> + <u>tol</u>	'from the ear'		<u>tol</u> + <u>ed</u>	'from you'
		<u>fej</u> + <u>tol</u>	'from the head'		<u>tol</u> + <u>ük</u>	'from them'

The suffixes are on our theory unspecified for the feature Back. The independent stems that correspond to them are for the most part likewise unspecified for the feature Back. Therefore they show up with front vowels, as in (60b). Other examples are -ban/-ben 'in', -ba/-be 'into', -nak/-nek 'dative', -val/-vel 'with'. However, there are at least two suffixes which alternate by the ordinary Backing harmony but have back vowels when used as suffixes, namely -ról/-ről 'off' and -nál/-nél 'at', e.g. ház + ról, fül + ről but rol + am. From our point of view, they must be specified Back when independent and be unspecified when suffixal. The underlying representations of these morphemes must clearly have Back vowels and this specification must be eliminated when they are used as suffixes. The elimination of the specification Back is simply a consequence of the general condition in Hungarian that Back is never specified in any suffix of the language (excepting some which are preceded by an internal # boundary and thus do not belong to the same harmonic domain as the stems they are added to, cf. Vago 1980, p.17-18). The elimination of the specification Back need not, then, be done by the harmony rule, and indeed in the present theory it could not be done by that harmony rule. There is no evidence in Hungarian for a front-back contrast in any suffixes subject to harmony. Thus Hungarian confirms our assumption that harmony applies to unspecified vowels, and that rules deleting inherently specified features are not found in domain harmony systems.

back
does not
this is not
(42)

We also are in a position to explain Vago's interesting observations concerning truncated diminutives of personal names. Their morphological pattern is illustrated in (61):

(61)	Ferenc	Feri	Feri + nek
	Erzsébet	Erzsi	Erzi + nek
	Klára	Klári	Klári + nak
	Zsuzsanna	Zsuzsi	Zsuzsi + nak

Stems with a neutral vowel in the first syllable followed by a back vowel naturally take back suffixes by the general rule, e.g. Tibor + nak, Eva + nak. Surprisingly, they take front suffixes when truncated: Tibi-nek, Evi-nek. This follows from our theory, where the B harmony is inherently associated with the ^{rhyme} vowel ^{of the second syllable} and must be deleted when the syllable ^{containing that} vowel ^{is} deleted in the truncated diminutives:

(62)

$$\begin{array}{c}
 \text{B} \\
 | \\
 \text{tIbor} + \text{I} \rightarrow \text{tIbI} \rightarrow \text{tIbI} + \text{nEk} = \underline{\text{tibinek}}
 \end{array}$$

Let us emphasize that this is now a necessary consequence, not an ad hoc stipulation as in theories that admit abstract vowels such as /ɨ/ into the underlying inventory.

Besides the Backing Harmony process that we have dealt with so far, Hungarian also has a limited form of Rounding Harmony. This is reflected in a constraint on the cooccurrence of vowels within morphemes which, in Vago's formulation, prohibits "polysyllabic morphemes in which an unrounded front vowel is followed by the vowel ö."

* i ö
e

(63) * + . . . { i, í, e, é } C_o ^o . . . +

(Vago 1980,20). Rounding Harmony also, together with Backing Harmony, creates a three-way alternation o ~ ^o ~ e in a number of suffixes such as -hoz ~ ^{-höz} ~ hez 'to':

(64)

ház + hoz	'to the house'
fűl + ^{höz}	'to the ear'
fej + hez	'to the head'

This contrasts with the two-way alternations a ~ e from underlying A:

(65)

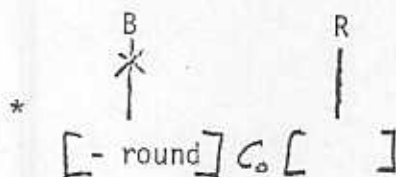
ház + nak
fűl + nek
fej + nek

Let us observe that there is no general rounding harmony in Hungarian. The only cases involve short o ~ ^o ~ e as illustrated in (64). Let us then suppose that, in addition to the feature [Back], also the feature [Round] is autosegmentalized for this particular vowel. Since suffixes subject to vowel harmony are unspecified for the autosegmentalized feature, we obtain as the underlying specification the vowel E, a mid vowel unassociated with either the autosegment Back or the autosegment Round. To obtain the correct pattern of rounding harmony for E we require the following (cyclic) rule:

(66)
$$V \rightarrow \overset{\text{Round}}{\downarrow} V$$

By virtue of strict cyclicity, this rounding rule cannot apply to vowels inherently specified for rounding. By virtue of WFC (63), or rather its autosegmental equivalent (67), it cannot apply after neutral-vowel stems, as in fej+hez (68a), but it does apply to give e.g. ház + hoz, fűl + höz (68b,c):

(67)



(68) (a) fEj + hEz (rule (65) blocked by WFC (66)) = fej + hez ←

(b)
$$\overset{B}{\downarrow} \text{h} \acute{\text{a}} \text{z} + \text{hEz} \rightarrow \overset{B}{\downarrow} \text{h} \acute{\text{a}} \text{z} + \text{haz} \rightarrow \overset{B}{\downarrow} \text{h} \acute{\text{a}} \text{z} + \overset{R}{\downarrow} \text{h} \acute{\text{o}} \text{z} = \text{h} \acute{\text{a}} \text{z} + \text{h} \acute{\text{o}} \text{z}$$

(c)
$$\overset{''}{\downarrow} \text{f} \text{ü} \text{l} + \text{hEz} \rightarrow \overset{''}{\downarrow} \text{f} \text{ü} \text{l} + \overset{R}{\downarrow} \text{h} \acute{\text{o}} \text{z} = \text{f} \overset{''}{\downarrow} \text{ü} \text{l} + \text{h} \overset{''}{\downarrow} \text{o} \text{z}$$

Nash (p.74) further observes that no verbs end in u underlyingly. It appears that disyllabic verbal roots show the pattern in (70):

(70)	a	a	i	a	u	a
	a	i	i	i	u	i
	*a	u	*i	u	*u	u

The restriction, then, is that the vowel u is excluded in root-final position: ³

(71)	*R
	v]
	Root

Finally, it is apparent that there is no underlying contrast between i and u in noun suffixes. High vowels in them show up as i after i and as u after a,u. Nash assumes underlying u and I shall propose below that they are unspecified.

These constraints have to be stated in any grammar accounting for Warlpiri vowel harmony, and I shall carry them over unchanged from Nash's treatment into my own. I shall, however, propose another interpretation of the harmonic processes themselves. Nash shows that SAT requires the features Labial and High to be represented autosegmentally on separate tiers. He proposes two rules which delete the inherent feature specifications on verb roots and on suffixes in the appropriate environments, which together with a rule telescoping sequences of identical features under certain conditions trig-

3. Warlpiri. The significance of this Australian language for MAT is that it has in earlier work been regarded as having a vowel harmony rule that changes the feature specifications of vowels, thereby merging an underlying i ~ u contrast that appears in harmonically neutral contexts (Hale 1973, Steriade 1979, Nash 1980). Moreover, vowel harmony in Warlpiri is said to be both progressive and regressive, depending upon the morphological structure of the word. In this section I shall argue that neither of these things is true, and that a much simpler account of Warlpiri system becomes possible in MAT.

The most complete analysis of Warlpiri vowel harmony is contained in Nash (1980). It is based on SAT, with the additional incorporation of a version of the Obligatory Contour Principle originally proposed by Leben (1978, 181) for tone systems.

Warlpiri has the three vowels i, a, u. Harmony is reflected in certain co-occurrence restrictions on the high vowels i and u, and in corresponding alternations between those vowels in suffixes, enclitics, and verb roots.

Within morphemes, as well as in words, i cannot be followed by u unless p or w intervenes. There are, accordingly, such noun stems as pipipuka 'bereaved father (used by classificatory mother to the bereaved)', yirriwu 'Acacia ancistrocarpa (bush)', but noun stems like *pipituka, *yirriju are impossible. Similarly, there are stem + clitic combinations like wajirrki+puru 'during wet time', but none involving such sequences as i + tu, i + ku, i + nyu. Accordingly, Nash (p.73,97) proposes a condition prohibiting the configuration

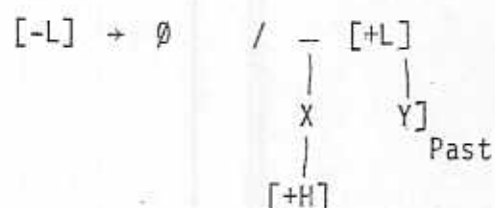
(69) * i [-labial] u

"either root internally underlyingly, or throughout a word's surface form, no matter what lexical category".² Let us already note that this is a perfect example of the structure-preserving character of vowel harmony, which the MAT is designed to explain.

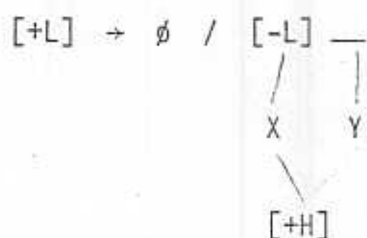
gers the general spreading conventions of autosegmental theory. The spirit of the MAT is to eliminate such language-particular rules so far as possible and, exploiting the structure-preserving properties of harmony, to derive their effects from the well-formedness conditions which are required for the lexicon anyway. Let us examine the two alternatives in turn.

Nash's rules are as follows (L = Labial, H = High):

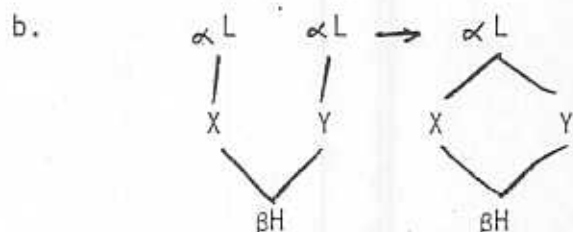
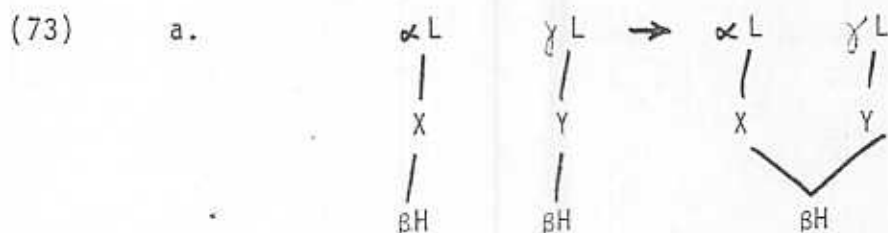
(72) a. Regressive Harmony



b. Progressive Harmony

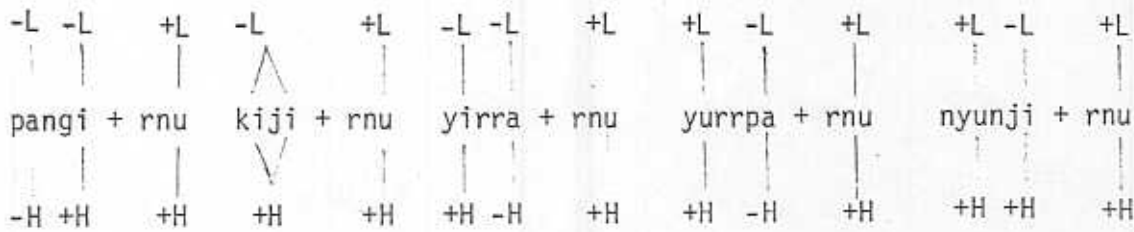


Their operation depends on the following Obligatory Contour Principle, which applies at all stages of the derivation:

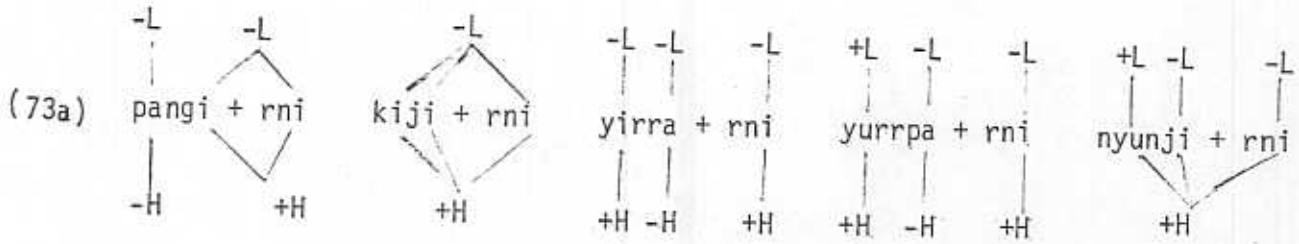
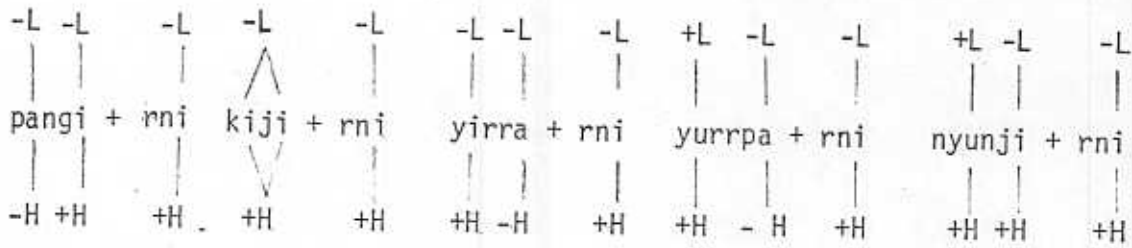


It is evident that (73) contains a core which belongs in the theory; still, the particular relation between the features High and Labial that it expresses presumably not the same in all languages.

Thus, Nash derives the verb paradigms as shown in (74) and the noun paradigms as shown in (75):

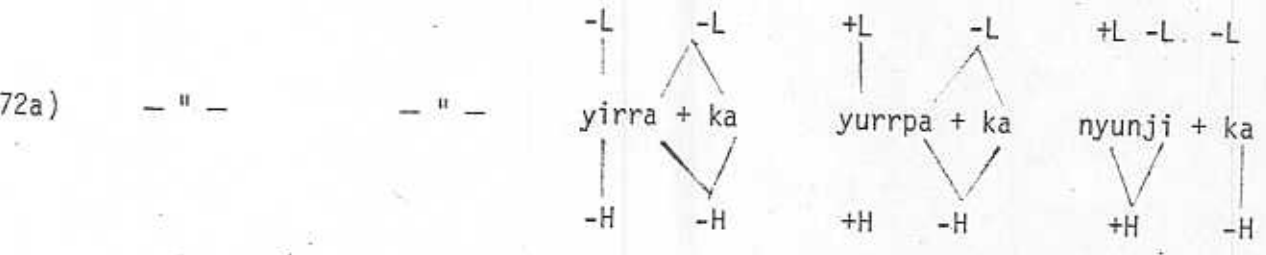
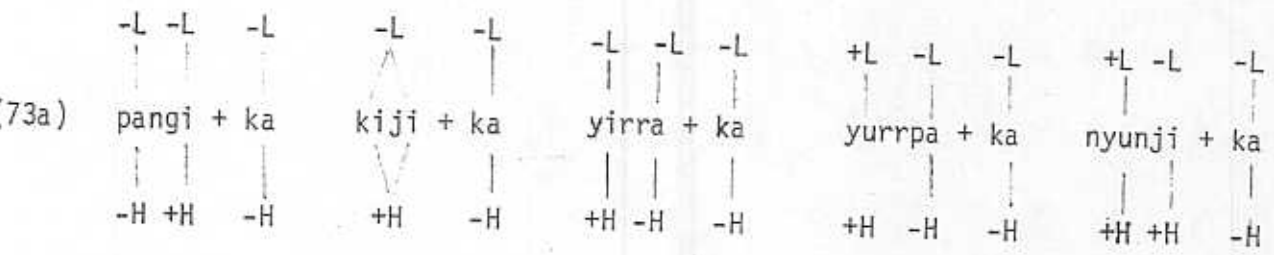


pangurnu kujurnu yirrarnu yurraparnu nyunjurnu



(72a) - " - - " - - " - - " - - " -

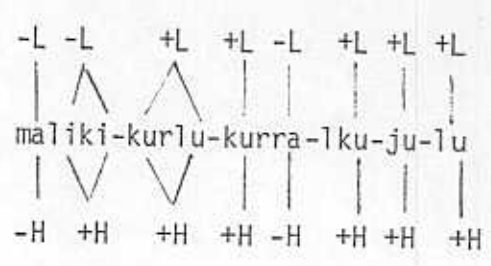
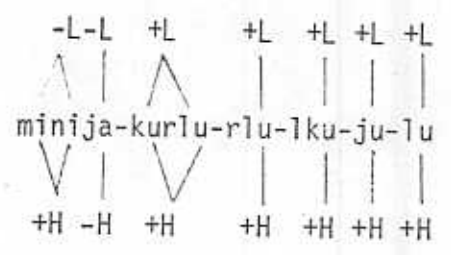
pangirni kijirni yirrarri yurrrparni nyunjirni



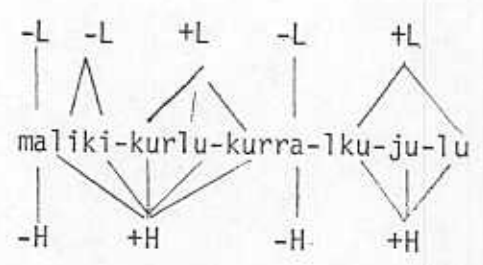
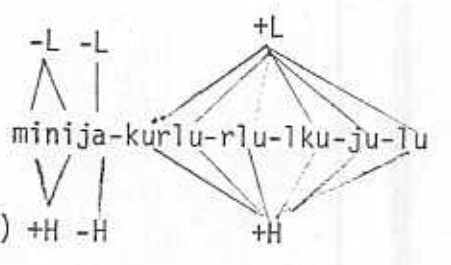
72a) - " - - " - - " - - " - - " -

pangika kijika yirraka yurrrpaka nyunjika

(75)

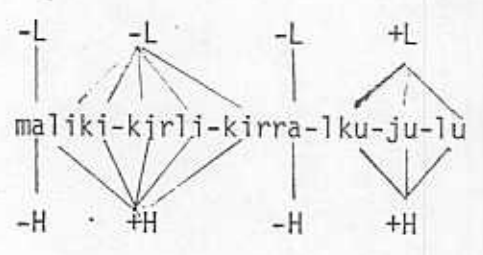


(73a)

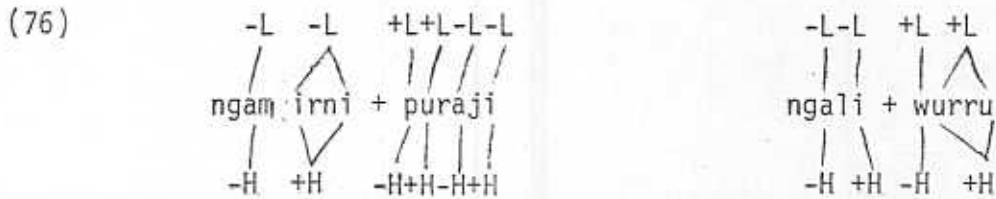


(72b)

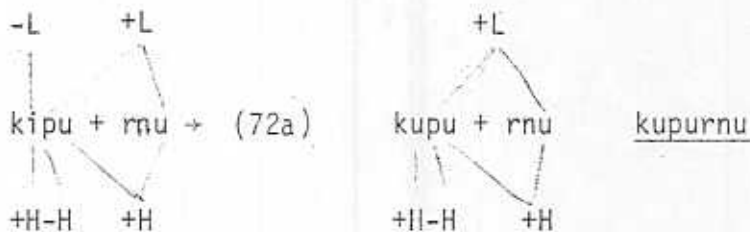
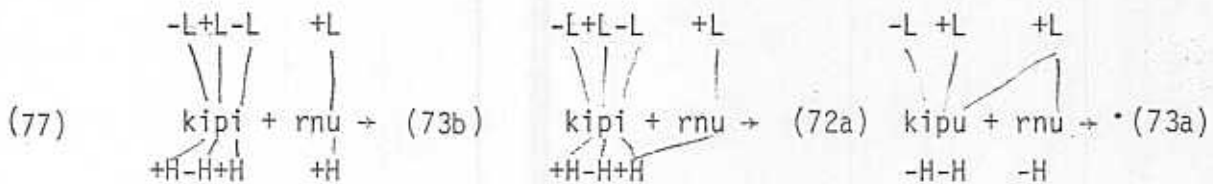
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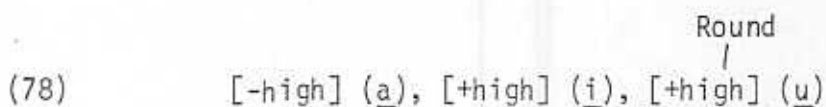
In his theory, progressive harmony (72b) is a delabialization (unrounding) of u to i. In order to prevent it from applying to clitics like puraji 'your' or wurru "Emphatic", which all begin with p or w, Nash proposes that these consonants are represented autosegmentally as [+Labial] and [-High]. This blocks progressive vowel harmony as shown in (76),



while allowing regressive harmony to operate, by alternating iteratively with the Obligatory Contour Principle:

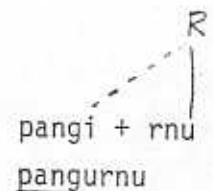

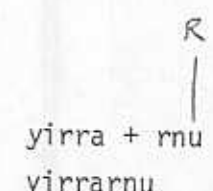
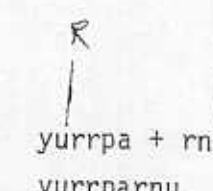
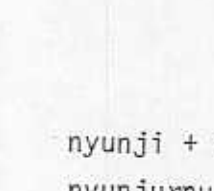
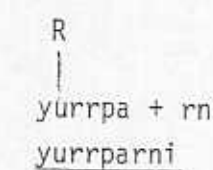
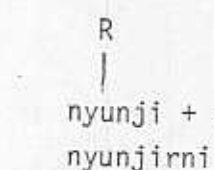
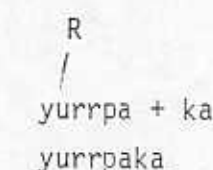
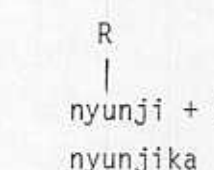


This SAT treatment can be simplified to a great extent under MAT assumptions. It is clear that only the feature Round, not also the feature High, is autosegmentalized in Warlpiri. The vowel system is thus as in (78):



(I shall here drop my convention of capitalizing the symbols representing vowels unassociated with the harmonic autosegment). In Warlpiri the vowel a is neutral harmonic, i.e. opaque (subject to both WFC's (31) and (32) of section 1). Similarly, labials seem to behave as opaque segments in nouns, as shown by such stems as pipipuka, yirriwu (69 above). By virtue of the opacity of p and w these words satisfy the condition of maximal association (35). It is of course met in verbs like nyunji because of WFC (71).

Regressive harmony now follows from the ordinary autosegmental conventions. A solid line in (79) indicates an inherent association in the lexicon and a dotted line shows the spread of the harmonic autosegment:

(79)	 <p>pangi + rnu <u>pangirnu</u></p>	 <p>kiji + rnu <u>kujurnu</u></p>	 <p>yirra + rnu <u>yirrarnu</u></p>	 <p>yurra + rnu <u>yurrparnu</u></p>	 <p>nyunji + rnu <u>nyunjurnu</u></p>
	<p>pangi + rni <u>pangirni</u></p>	<p>kiji + rni <u>kijirni</u></p>	<p>yirra + rni <u>yirrarni</u></p>	 <p>yurra + rni <u>yurrparni</u></p>	 <p>nyunji + rni <u>nyunjirni</u></p>
	<p>pangi + ka <u>pangika</u></p>	<p>kiji + ka <u>kijika</u></p>	<p>yirra + ka <u>yirraka</u></p>	 <p>yurra + ka <u>yurrpaka</u></p>	 <p>nyunji + ka <u>nyunjika</u></p>

A further point to be observed is that the operation of vowel harmony yields root-final u in this case, as well as in /kiji + rnu/ → kuju + rnu. The reason this is not a violation of WFC (71) is that the Bracketing Erasure Convention eliminates the inner brackets in the structure [kuju]+rnu before vowel harmony can apply.

Turning now to suffixal harmony, our theory forces us into a new analysis. We cannot, as in previous treatments, assign all noun suffixes underlying /u/ and postulate a rule which unrounds them after i, provided no labial intervenes. If those suffixes have no contrast between i and u, they must have underlying i by MAT assumptions, since that is the unmarked value. We

therefore require instead a rounding rule $i \rightarrow \overset{R}{i}$. This turns out to be an advantageous consequence of the theory, for the rounding rule can then be allowed to apply in the maximally general, context-free form. In the one context where it must not apply to noun suffixes, namely, $i[-\text{labial}]$, it will be blocked by WFC (35), while the sequence $i [+ \text{Labial}] \underline{u}$ is permissible because labials are opaque in nouns:

(80) $a + Ci \rightarrow a + \overset{R}{Cu}$

$i + ti$ (no change) vs. $i + pi \rightarrow i + \overset{R}{pu}$

$\overset{R}{u} + Ci \rightarrow \overset{R}{u} + Cu$ (rounding is vacuous)

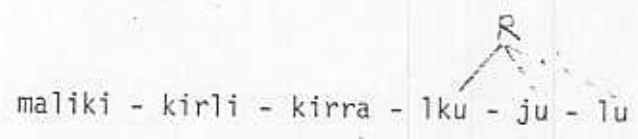
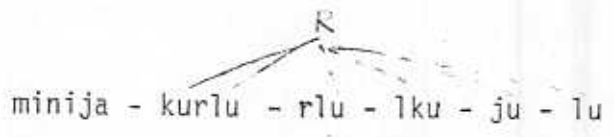
If we assume that the rounding rule is cyclic, then its correct application in noun suffixes, and its failure to apply in noun stems and in verbs, is predicted in its entirety by the independently motivated well-formedness conditions of Warlpiri in conjunction with the theory of MAT and the principles of the phonological cycle. The rounding rule itself is entirely context-free:

(81) $[] \rightarrow [\overset{R}{i}]$

Rule (81) only applies to i but this restriction need not be stated in the rule itself. The reason it does not apply to the vowel a (or to consonants) is that they are neutral, i.e. subject to WFC (31). It does not apply even to i if preceded by the sequence i + labial. This restriction also need not be stated in the rule because it follows from WFC (64). It does not apply to the i's of noun stems and verb suffixes because i and u are distinct in them and the rule would therefore be feature-changing, and feature-changing cyclic rules cannot apply in non-derived contexts. It does not apply to the i's that precede the opaque vowel a in verb roots either because, again, there is an inherent contrast between i and u there (e.g. yirra- vs. yurrpa-). It does not apply to the final vowel of verb roots because of WFC (71). From our point of view, therefore, there really is no "suffix harmony" at all in Warlpiri. (81) is rather the maximally stripped-down version of the type of rule we have encountered in the Finnish Backing rule and the Hungarian Rounding rule in sections 1 and 2 above.

The derivations in (82) show how rule (81) applies to a string of suffixes.

2)(a) minija - kirli - rli - lki - ji - li (b) maliki - kirli - kirra - lki - ji - li



A further advantage of our solution is that it simplifies the treatment of the two clitics rni 'hither' and rli 'we (Dual Inclusive)'. In western and northern Warlpiri they show up with i after a, i and with u after u:

- (83)
- | | | | | | | | |
|--------|---|----|---|-----|---|----------|---------------------------------------|
| parnka | + | ja | + | rni | + | rlijarra | 'run - Past - hither - we Du. Excl.' |
| yan | + | i | + | rni | + | rlijarra | 'go - N Past - hither - we Du. Excl.' |
| yan | + | u | + | rnu | + | rlujarra | 'go - Past - hither - we Du. Excl.' |

The SAT analysis requires a special rule for this $\underline{i} \sim \underline{u}$ alternation, which Nash (p.82) writes as a cyclic, segmental, non-propagating assimilation rule:

$$(84) \quad i \rightarrow u / u] C_{\text{or}} +$$

Observe that the rule applies twice in the last example of (83). In the alternative analysis proposed here, rni and rli are marked as exceptions to the rounding rule (81), see (83a). The general autosegmental conventions then ensure that R spreads onto them from u (85b):

(85) a. parnka + ja + rni + rlijarra ((81) does not apply)

b. yan + ^Ru + rni + rlijarra = yanurnurlujarra

In the other dialects, rni, rli have invariable i. From our point of view they are in those dialects marked as having opaque vowels. The same is true in all dialects for the monosyllabic clitic yi 'continuative' and a group of polysyllabic clitics with invariable i, e.g. pinki 'etc.', pinangi(w) 'only, any', kirli 'exactly' (Nash, p. 83,96).

It is clear that the MAT allows a far simpler description of Warlpiri vowel harmony than the SAT. To be sure, the relative complexity of descriptions in different theoretical formats in itself need not be significant. But in this case it corresponds to a genuine advantage of the MAT, namely that it brings out certain generalizations which are lost in the SAT. These generalizations involve the structure-preserving property of vowel harmony systems. In particular, the WFC (69) ^{or its consistent} is needed in any description but only in the MAT theory does it predict the phonological conditions on the "suffix harmony" rule. Similarly, the WFC (71) is needed in any description but only in the MAT theory does it predict root harmony, allowing that rule to be dispensed with entirely.

4. Mongolian. Not infrequently, Backing harmony occurs together with Rounding harmony. Turkish is the most familiar example, but it possesses a symmetrical vowel system and therefore sheds little light on the problems under discussion here. Mongolian, on the other hand, has such a system with a neutral vowel. It has in fact proved recalcitrant to earlier versions of autosegmental theory. Anderson (19 —) has cited it as a counterexample. Chinchor (1979) and Steriade (1979) have suggested certain changes to overcome the difficulties. We shall here show a satisfactory solution consistent with MAT.

The vowels of Mongolian are given in (86):

(86)	i	ü		u
	e	ö	a	o

Backing and rounding harmony restrict their co-occurrence in stems, and likewise in entire words, according to the following generalizations (quoted from Chinchor 1979). For backing harmony, the restrictions are:

- (87) (i) All the vowels of a word are either [+back] or [-back].
 (ii) The only exception to this is /i/ in non-initial syllables. It can occur in words which are [+back].
 (iii) When /i/ is in the initial syllable, all of the other vowels in the word are [-back].

These constraints are exemplified in the following data:

(88)	<u>xii + yee</u>	'let's (or let me) do it'
	<u>orxi + yoo</u>	'let's throw it away'
	<u>oro + yoo</u>	'let's enter'
	<u>yaba + yaa</u>	'let's go'
	<u>suu + yaa</u>	'let's sit down'
	<u>nee + yee</u>	'let's open'
	<u>ögö + yöö</u>	'let's give'
	<u>nuu + yee</u>	'let's move'

For rounding harmony, the restrictions are:

- (i) If a word has only non-high vowels, then they are all either [+round] or [-round].
- (ii) The [+high, +round] vowels can appear in non-initial syllables of words containing otherwise [-round] vowels.
- (iii) Following [+high, +round] vowels there are only [-round] vowels.
- (iv) When /i/ is in the initial syllable, all nonhigh vowels following are [-round].
- (v) When /i/ is in a non-initial syllable, it can appear in words which are otherwise [+round].

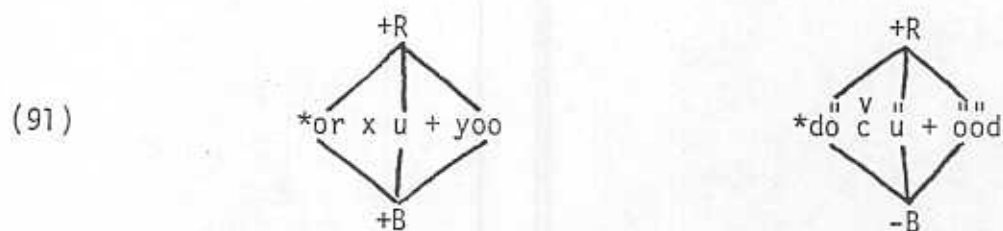
The rounding harmony among the four nonhigh vowels is shown by our previous example: the suffix there is -yoo, -yöö if the stem has nonhigh rounded vowels, otherwise it is -yaa, -yee, depending upon Backing harmony. The nonhigh vowels are therefore mutually noncontrastive beyond the first syllable. There is no rounding harmony for high vowels so that the vowels u/ü (see 89a) contrast with (invariable) i (see (89b):

- | | | |
|-------|--|-----------------|
| (89a) | dag + uu ^l | 'to take along' |
| | or + uu ^l | 'to bring in' |
| | med + u ^u ^u | 'to let know' |
| | giig + u ^u ^u | 'to enlighten' |
| | xög ^v + u ^u ^u | 'to develop' |
| | uz + u ^u ^u | 'to show' |
| | | |
| (89b) | xor + i ^ŋ | 'twenty' |
| | dö ^v c + i ^ŋ | 'forty' |

The problem arises in words where rounding harmony spreads across a syllable with i:

- (90) orxi + yoo 'let's throw it away' (suffix -yee ~ -yöö ~ -yaa ~ -yoo)
 morin + oos 'from the horse' (suffix -ees ~ -öös ~ -aas ~ -oos)
 döci + öod 'by forties' (suffix -eed ~ -ööd ~ -aad ~ -ood)

Spreading of the autosegmental features [+ Round] and [± Back] will yield (91):



The strategy of letting the neutral vowel i undergo harmony and recapturing its correct phonetics by a later unrounding rule runs into the difficulty that underlying high rounded vowels u/ü must not be unrounded.

From our point of view, there is no problem. A well-formedness condition is needed in any case to exclude the vowel *i from the inventory. With the features Back and Round as autosegmental, this well-formedness condition says that unrounded high vowels are neutral w.r.t Back, i.e. that high vowels cannot be associated with Back if they are not associated with Round:



All vowels except the neutral vowel i are harmonic, i.e. subject to (32) for both $F = \text{Back}$ and $F = \text{Round}$. That is, Mongolian has no opaque vowels. Moreover, Mongolian has WFC (35), which requires the maximal association of Back and Round that is allowed by the well-formedness conditions, within the domain of a word.

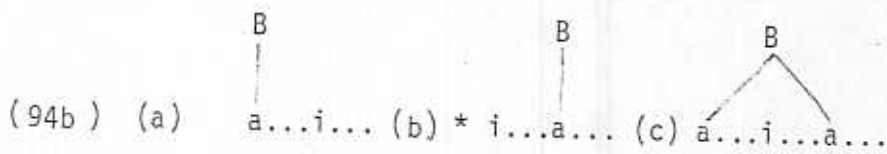
These WFC's interact with two sequential WFC's that control the distribution of the features Round and Back. Both contain a certain left-right asymmetry. If we consider backness harmony, we see that words containing the vowel sequence a...i... are possible, but words beginning the vowel sequence *i...a... are not possible, although a...i...a... is again allowed. The appropriate constraint is that in the configuration

$\begin{matrix} B \\ | \\ [X \ V, \end{matrix}$ B must be linked to some vowel in X if there is one:

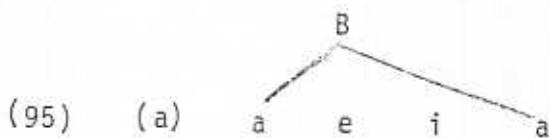


where X contains V

Consider now the linkings in (94):

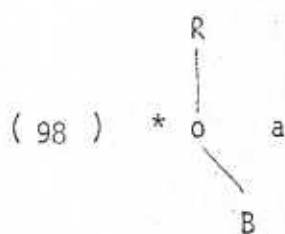
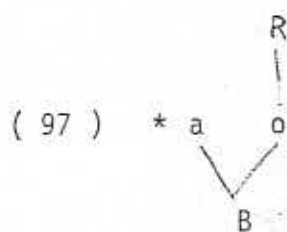


In (b) and (c), WFC (93) prohibits i from being linked with B; as a result (b) violates WFC (92) and constitutes an impossible vowel sequence. A sequence such as * a...e...i...a is also correctly excluded. It violates well-formedness condition (35), which requires the maximal possible association of autosegments:

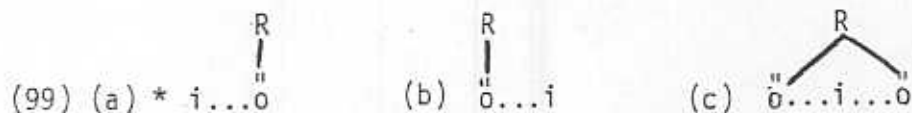


The basic fact of rounding harmony is that rounding spreads always among nonhigh vowels, and only among them. High vowels (u/ü) can occur with distinctive rounding in noninitial syllables (e...ü and e...i), but nonhigh vowels cannot (o...e but not *e...o).

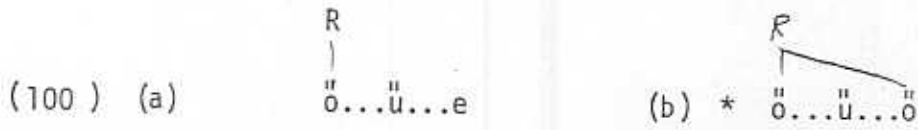
We therefore take Rounding as autosegmentalized and generalize (93) to it. High vowels are neutral, i.e. cannot be associated with the autosegment Round (WFC 31). We distinguish i from ü, u by the segmental specification [\pm round]. Furthermore, vowels with the features $\left[\begin{array}{l} + \text{ high} \\ + \text{ round} \end{array} \right]$ are harmonic w.r.t. the autosegment Round (WFC 32). This together with the proposed universal conventions of autosegmental phonology, correctly blocks vowel sequences such as e...ü, a...o, ü...e, o...a. Cf. (97):



The asymmetry of * i...ü vs. ü...i is accounted for, as well as the previously problematic transparency of i:



Similarly, such vowel sequences as $\ddot{u} \dots \ddot{o}$, $\underline{u} \dots \underline{o}$ are blocked, while $\ddot{u} \dots \underline{e}$, $\ddot{u} \dots \underline{i}$, $\underline{u} \dots \underline{i}$ etc. are correctly permitted. Observe also that unlike \underline{i} , \underline{u} and \ddot{u} are opaque:



The deviant vowel sequence (100b) has no representation consistent with WFC's (35, 33). Similarly, we have $\underline{u} \dots \underline{i} \dots \underline{a}$, but not * $\underline{u} \dots \underline{i} \dots \underline{o}$, * $\underline{u} \dots \underline{i} \dots \underline{e}$, or * $\underline{u} \dots \underline{i} \dots \underline{\ddot{o}}$, which would all violate the WFC's.

5. Akan. The vowel harmony system of Akan, a Kwa language of Niger-Congo, has been studied by Clements (1980). His findings are reviewed briefly here because of their bearing on our claim that vowel harmony is structure-preserving.

Phonemically, Akan has nine vowels, grouped into two sets according to their specification for the feature [\pm Advanced Tongue Root]:

(101)	i	u	ɪ	ʊ
	e	o	ɛ	ɔ
			a	
	[+ATR]		[-ATR]	

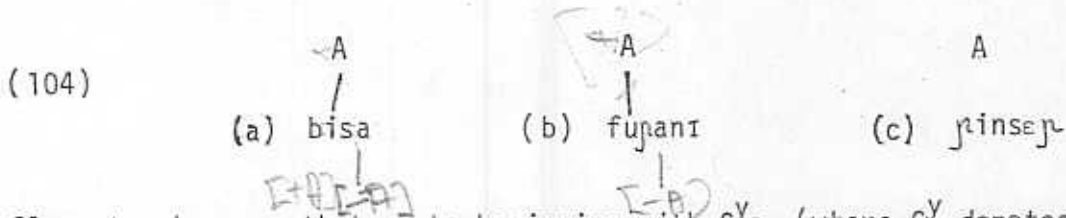
In words containing no low vowels, all vowels must be either [+ATR] or [-ATR], e.g. e-bu-o 'nest', ɛ-bʊ-ɔ 'stone'. The low vowel a co-occurs with either set, e.g. bisa 'to ask', pira 'to sweep'. Moreover vowels of the two sets freely cooccur if a intervenes, e.g. fɛnani 'to search', and only exceptionally otherwise, e.g. ɛnsɛni 'to be pregnant'. Prefix and suffix harmony are controlled by the first and last root vowel, respectively, e.g. o-bisa-ɪ 'he asked (if)'; o-ɛnsɛni-ɪ 'she became pregnant'.

Akan, then, has a vowel harmony system of the simplest kind. Following Clements, the feature [ATR] is autosegmentalized and affixes are taken to be inherently unspecified for this feature. The opaque behavior of the vowel a is reflected in our theory by designating it as both neutral and harmonic by the appropriate instantiations of WFC's (31) and (32), respectively. Thus, a is neutral by (102) and all vowels are harmonic by (103):

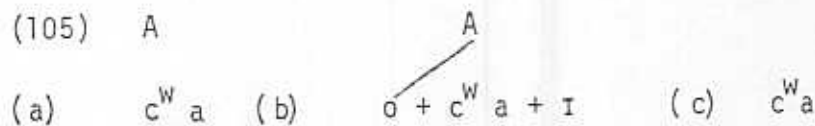


This treatment is entailed by the constraints inherent in MAT; the fact that it has several welcome consequences in Akan therefore comes as support for that theory. First, the phonetic value of a as [-ATR] is correctly

predicted by the equivalence (24). Second, according to Clements, Akan disallows sequences of [+ATR] and nonlow [-ATR] vowels, with the exception of one or two roots such as the root ɲinseɲ cited above. We may then ask why [+ATR] vowels can abut the low [-ATR] vowel a with impunity. But precisely this distribution follows from the assumption that Akan is subject to WFC (35) (requiring maximal permissible association of the harmonic feature within words) if a is subject to (102) and (103) as proposed here. This admits (104a,b) as harmonically regular roots (and words) but renders (104c) exceptional, as desired, since association is maximal in (a,b) but not in (c):



Clements observes that roots beginning with c^ya (where c^y denotes a palatalized or labialized consonant) unexpectedly take [+ATR] prefixes, e.g. o-c^wa-ɪ 'he cut it'. He proposes that they carry a floating autosegmental element, so that their lexical representation is as in (104a). If a prefix is added, the floating ATR "docks" onto it (104b); otherwise (104c) it deletes by convention (15d).



The restriction noticed by Clements that the floating autosegment exists only when the root vowel is a follows from the independently given WFC (35).

We have not yet mentioned what is for our present concerns perhaps the most interesting aspect of Akan vowel harmony. The [+ATR] counterpart of a, missing from the underlying inventory, does occur phonetically in the environment before [+ATR]. Cf. the examples (106), where [ạ] denotes this vowel.

- (106)
- | | |
|------------------------|--------------------|
| kari | 'to weigh' |
| ạ+furuma | 'navel' |
| piɾako | 'pig' |
| wə + s ^v aɪ | 'he has descended' |

Syllables further to the left are also affected, to a lesser degree. Moreover, the process of "Vowel Raising" which introduces [a̠] applies also across word boundaries, when a [+high, +ATR] vowel follows. This environment reveals that Vowel Raising applies not just to a, but to all other [-ATR] vowels as well:

(107) (a)	ɲɲ ^{wa}		'snail'
	ɲɲ ^{wa}	nɔ	'the snail'
	ɲɲ ^{wa}	bi	'a snail'
	ɔwɔ		'snake'
	ɔwɔ	nɔ	'the snake'
	ɔwɔ	bi	'a snake'

Inside words the process is detectable only for a because a is the only [-ATR] vowel that occurs before [+ATR] vowels.

At first blush the "Raising" of a to a̠ seems to constitute a counter-example to our claim that vowel harmony is structure-preserving. WFC (102), which requires a to be unassociated to ATR, is apparently violated by Vowel Raising. However, Clements gives reasons to believe that Vowel Raising really is not a harmonic process at all, in fact not even a phonological rule. Rather, it is a coarticulation process by which a string of syllables is pronounced with increased Tongue root advancing in anticipation of a Following +ATR vowel. That is, the phonetic representations of Akan maintain WFC (102) in its entirety: a is never associated with +ATR. The raised variants a̠, ɔ̠, etc. of the -ATR vowels arise in the conversion of phonetic representations to motor commands. Akan vowel harmony is therefore strictly structure-preserving in our sense.

FOOTNOTES

1 WFC (15a) can be strengthened to disallow many-one associations between autosegments and segments except for tonal elements, where they are clearly required for contour tones. Cf. also McCarthy (1979) for the exclusion of (non-tonal) many-one associations in connection with Semitic vowel patterns. However, on the version of autosegmental vowel harmony that I shall propose here, all of (15 a-c) can be dispensed with.

2 Actually, the constraint may be more severe. Nash (p. 75) cites no examples of ipu, iwu in the first two syllables of a stem, so that *kipu, *kipuna are perhaps excluded. This would explain also why the Pintupi word jiwurra 'kindling' shows up in all Warlpiri dialects as jiwirri (Nash, p. 76).

3 As Nash points out (p. 81), this morpheme structure condition can be maintained also for monosyllabic verb roots, where two roots originally of the form /pu/, /yu/ can be reanalyzed as /pi/, /yi/ without loss of generalizations. Of the permissible combinations in (70), u...i is the rarest. Nash (p. 74-75) finds only nyunji 'kiss' and two other verbs of that form. If they are considered deviant, (70) can be generalized to exclude u in a root-final sequence of high vowels.