MORRIS HALLE AND JEAN-ROGER VERGNAUD

HARMONY PROCESSES*

Harmony processes characteristically regulate the distribution of a given feature or feature complex in specific, not necessarily contiguous phonemes of a word. For example, in Finnish words the back-front contrast in rounded and in low vowels – but not in nonlow unrounded vowels – agrees with that of the stem, whereas in Navaho words, the contrast of anterior-nonanterior in coronal affricates and continuants – but not in other phonemes – is determined by the last coronal affricate or continuant in the word. Harmony processes fall into two distinct types depending on whether the harmonic features propagate in one direction only, or whether the propagation occurs in both directions. We shall term the former type, directional harmony, and the latter type, dominant harmony. We propose that the facts of dominant harmony are best described with the devices of autosegmental phonology, whereas those of directional harmony are best characterized by making use of the tree construction developed in recent work in metrical phonology.[1] We illustrate these proposals in sections 1 and 2 below; in section 3 we compare the descriptive effectiveness of the two mechanisms in dealing with different bodies of data.

1. DOMINANT HARMONY ILLUSTRATED

In languages with dominant harmony the vowels fall into two sets: a dominant set and a recessive set. As a first approximation one can say that the morphemes of the language are of two kinds. Dominant morphemes have vowels which belong to the dominant set and which never alternate with vowels in the recessive set. Recessive morphemes, on the other hand, appear in two different shapes: in words containing a dominant morpheme the vowels of recessive morphemes belong to the dominant set; in words without dominant morphemes, all vowels belong to the recessive set.

A typical example of dominant harmony is provided by the East African language (or language group) Kalenjin. As described by Beatrice Hall et al. (1974) Kalenjin has the two sets of vowels shown in (1a).

W. Klein and W. Levelt (eds.), Crossing the Boundaries in Linguistics, 1–22.

(1a)

i	u	I	U
e	o	ɛ	ɔ
ɟ		a	

dominant: [+ATR] recessive: [-ATR]

Our authors report that "within a phonological word Dominant morphemes (those with [=ATR] vowels) cause contiguous Recessive morphemes (those with [-ATR] vowels) to shift harmonic series and become [+ATR] . . . If there is a [+ATR] vowel in the word whether in the root, or in the affix, then all Recessive vowels become [+ATR]." But if there is no [+ATR] vowel in the word, all vowels in the word remain [-ATR]. These facts are illustrated in (1b):

(1b) kI-a-gɛr "I shut it" kI-a-bar-In "I killed you (sg.)"
ki-ɟ-ge:r-in "I see you (sg.)" ki-ɟ-ger-e "I was shutting it"

Kalenjin has three morphemes that can be classed as neither dominant nor recessive. Following the Halls we shall term these morphemes *opaque*. To quote our source: "Opaque morphemes are those with [-ATR] vowels which do not shift harmonic class when contiguous to a dominant morpheme . . . The three opaque affixes which we have found . . . are the negative prefix *ma-*, the perfectivizer *ka-*, and the reflexive suffix *kɛ* . . . Opaque affixes . . . prevent harmony from applying to preceding (and/or following -MH/JRV) morphemes."

(1c) i. ki-a-un-gɛ: "I washed myself" ma-ti-un-gɛ: "don't wash youself"
ii. ka-ma-ɟ-ge:r-ɟk "I didn't see you (pl.)" ka-ma-ga-go-ge:r-ɟ "and he hadn't seem me"

In (1ci) the vowel of the reflexive suffix [gɛ:]~[kɛ:] and of the negative prefix [ma] remain [-ATR], although the stem [un] "wash" is dominant and induces [+ATR] harmony in all morphemes contiguous to it. In (1cii) the negative prefix[ma] not only is unaffected by the [+ATR] induced by the stem [gɛ:r]~[kɛ:r] "see", but also blocks the spread of the harmony to the morpheme on its left.

The framework that seems to us most appropriate for dealing with the facts just sketched is that of autosegmental phonology pioneered by John Goldsmith (1974) in his dissertation. One of the central innovations of

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autosegmental phonology was to represent certain features or feature complexes on distinct autosegmental tiers which are separate from one another as well as from the phonological core. We refer to the entities on the different autosegmental tiers as *autosegments*. While the entities in the central core will be referred to as *slots*. Particular autosegments can be linked only to particular slots. Thus, in many languages tones are linked only to vowels, but not to consonants; but there are languages where tones are linked to sonorant consonants as well as to vowels. Autosegmental representations must, therefore, be subject to the formal requirement (1d):

(1d) For each autosegmental tier it is necessary to stipulate the class of slots in the phonological core to which the autosegments may be linked.

It is obvious that in the Kalenjin examples sketched above, it is the feature [ATR] that will be represented on a separate autosegmental tier (in a fashion to be detailed directly) and that we must stipulate that the [ATR] autosegments can be linked only to vowel slots.

We assume that the fact that a particular feature or set of features is represented on a separate autosegmental tier does not necessarily preclude the same feature or features from being specified also in the phonological core. However, when a slot in the core is linked to an autosegment, the specification of the autosegment overrides the specification in the core. Moreover, a distinction will be made between autosegments that are linked to one or more slots in the core, and unlinked or floating autosegments; i.e., autosegments that are not linked to any slot in the core. All associations between slots and autosegments are subject to the constraint that linking lines must never cross.

A number of further conditions on the linking of autosegments and slots have been proposed in the literature. In particular, Goldsmith (1974) has proposed for tonal autosegments the conditions (1e):

(1e) i. Each vowel slot is linked to at least one tonal autosegment.
ii. Each tonal autosegment is linked to at least one vowel slot.
iii. Floating tonal autosegments are linked to (vowel) slots one-to-one from left to right. Slots and autosegments remaining unlinked at this point are linked to their nearest accessible counterpart.

According to (1e) two or more tonal autosegments may be linked to a given vowel slot; and this possibility is made considerable use of in treating a variety

of tonal phenomena. It is amply motivated by the existence of contour tones and by the phenomenon of melody stability – i.e., by the important fact that when a vowel is deleted the tone associated with it frequently does not disappear, but shifts rather to an adjacent vowel. Since there are no analogous phenomena in harmony processes, somewhat different conditions will have to be imposed here. In particular, we propose that harmony processes are subject to the conditions in (1f) rather than those in (1e).

(1f) i. Each (vowel) slot is linked to at *most* one (harmony) autosegment.

ii. Floating autosegments are linked automatically to all accessible vowel slots.

iii. Unlinked autosegments are deleted at the end of the derivation.

In the light of these proposals we now examine the Kalenjin facts sketched above. We assume that in underlying representations all vowels are (redundantly) specified as [-ATR]. Dominant morphemes – and only they – are supplied in their lexical representation with a floating [+ATR] autosegment. The three opaque morphemes of Kalenjin are represented with a linked [-ATR] autosegment:

[–ATR]	[–ATR]	[–ATR]
|	|	|
ma	ka	kɛ

Typical underlying representations are shown in (1g):

(1g)

	[+ATR]	[–ATR] [+ATR]
kI-a-gɛr	kI-a-gɛr-ɛ	ka-ma-a-gɛ:r-ak
"I shut it"	"I was shutting it"	"I didn't see you (pl.)"

The first example in (1g), consisting exclusively of recessive morphemes, is subject to no modifications and surfaces in its underlying form as far as [ATR] harmony is concerned, since all vowels are redundantly specified as [-ATR]. In the second example all vowels are [+ATR] because the floating [+ATR] autosegment will be linked to all vowels as required by (1fii). In the third example, the word-initial syllable cannot be linked to the floating autosegment since such a link would cross the line linking the opaque morpheme *ma* to its [-ATR] autosegment. The absence of linking does not result in a

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ii. o-bisa-I
iii. pIrako "p
iv. o-ŋanI "h

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iii. pIrakɔ

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In his important paper on vowel harmony in Akan G. N. Clements (1980) provides excellent arguments showing that the facts of Akan vowel harmony are best dealt with by means of the autosegmental framework. We shall not review his discussion but only examine a few examples of vowel harmony in Akan as they shed light on the viability of condition (1f). Like Kalenjin, Akan is also subject to [ATR] harmony of the dominant-recessive type and it can be treated in the same general manner as Kalenjin requiring only a few minor modifications to account for certain differences between the two languages which we now list: a. Whereas in Kalenjin both stems and affixes may be either dominant or recessive; in Akan this option is available only to stems, suffixes are always recessive. (Cf. 2ai) b. Whereas Kalenjin has only three opaque morphemes, in Akan the low vowel /a/ is systematically opaque. This vowel does not participate in harmony processes and blocks the spread of the [+ATR] harmony to other syllables. (Cf. 2aii–iii) c. Unlike Kalenjin, Akan has a special class of morphemes which induce [+ATR] in affixes (=prefixes) but do not themselves contain any [+ATR] vowels. We illustrate these facts in (2a):

(2a) i. o-fiti-i "he pierced (it)" ɔ-cIrɛ-I "he showed (it)"
ii. o-bisa-I "he asked (it): ɔ-kari-i "he weighed it"
iii. pIrako "pig" fuŋanI "to search"
iv. o-ŋanI "he woke up" ŋanI "to awaken"

We obtain the correct results if we postulate the underlying representations in (2b):

(2b) i. ɔ-fItI-I ɔ-cIrɛ-I ii. ɔ-bIsa-I ɔ-karI-I
iii. pIrakɔ fuŋanI iv. ɔ-ŋanI ŋanI

All but the examples in (2biv) are self-explanatory. The examples in (2biv) show that in Akan the floating [+ATR] autosegment may appear in morphological contexts where it will have no vowel slot to which it can be linked.

Recall that in the case of tonal processes an unlinked tonal autosegment would be linked to the nearest vowel. In the case of harmony, however, unlinked autosegments are deleted as required by (1fiii).

The most striking examples known to us that bear on the difference between the autosegmental treatment of tonal processes and various kinds of harmony are provided by the South American language Capanahua. Our disscussion here is based on an as yet unpublished study by K. Safir (1979) and on the monograph by Loos (1969), which also was utilized by Safir. Capanahua is subject to nasal harmony of a very interesting kind. In this language vowels and glides are nasalized in position before nasal consonants. This process affects not only the phoneme immediately preceding the nasal consonant, but also any number of preceding glides and vowels provided only that no [+cons] segments intervene. Nasal consonants are subject to deletion in position before glide and word finally. Concomitant with this deletion, nasality spreads rightward, again affecting the entire consecutive substring consisting exclusively of [-cons] segments. We illustrate this in (3a):

(3a) cipõ*n*ki "down river" bãna-wi "plant it" wirãn-ai "I pushed it" hãma-wi "step on it" hãmã-ʔõna "coming stepping"[2]
wiran-wi > wirãw̃ĩ "push it over" wiran-yaʂa?n-wi > wirã-ỹãʂãʔ-w̃ĩ "push it over sometime"

What is crucial about the facts just cited from our point of view is that [+cons] slots block the spread of nasality. They act therefore like opaque slots in Kalenjin and Akan, and will be represented like these, i.e., with a linked [α nasal] autosegment. By contrast, vowels and glides, i.e., [-cons] slots, are not opaque and will therefore be represented without linked autosegments. To account for the spread of nasality we need two ordered rules. The first of these inserts a floating [+nas] autosegment to the left of a linked [+nas] autosegment. The second rule deletes a nasal consonant before glide and word finally. The conventions (1f) produce the correct outputs given the underlying representations shown in (3b):

(3b)

[–N]	[+N]							[–N]	[+N]							[–N]	[+N]		
	|							|							|			
b	a	n	a	-	w	i		w	i	r	a	n	-	y	a	ʂ	a	?	n	-	w	i

The Capanahua example is especially significant because it shows that the opaque autosegment only serves to block the dominant harmony, it does not

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initiate a harmony of its own. In the cases from Kalenjin and Akan discussed above this was not self evident; the same output would have been produced if the opaque segments had been allowed to initiate a "recessive" harmony of their own. In the Capanahua case this alternative is excluded, for if the opaque /n/ in *banawi* had been allowed to initiate its own harmony all but the initial stop of the word would have been nasalized in obvious contradiction of the facts of the language.

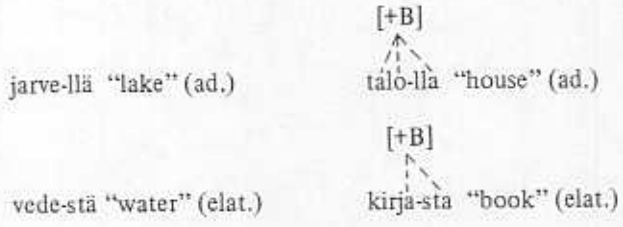
Our last example of dominant harmony is that of Finnish. Finnish has usually been treated as an example of directional harmony since the harmonic feature – backness – is always propagated from left to right. This fact, however, is not basic but rather a consequence of two other, more fundamental facts, namely, that in Finnish, like in Akan, only stems may be either dominant or recessive but affixes are always recessive, and secondly, that in Finnish there are no prefixes. As a result harmony can only spread rightward, from a stem to the suffixes.

Finnish vowels are traditionally classed into two sets: a harmonizing set consisting of vowels that are either [+round] or [+low], and a neutral set, consisting of the vowels [i,e] which are [-round, -low]. Only vowels of the former set participate in harmony; vowels of the latter set are never affected by harmony. To account for this fact, we shall assume that Finnish vowel harmony is subject to the stipulation that

(4a) autosegments on the tier for the feature [back] may be linked only with vowel slots which are either [+round] or [+low].

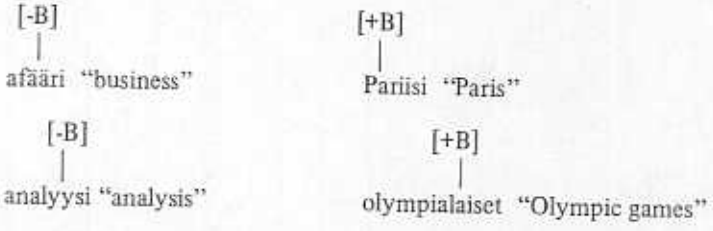
A second dichotomy that has long been recognized is that of harmonic and disharmonic stems. Harmonic stems occur in words where all vowels are either [-back] or [+back]. To capture this formally all vowels in the phonological core will be redundantly specified as [-back]; this applies both to stem- and suffix-vowels. Harmonic stems that trigger [+back] harmony are, moreover, supplied in their lexical representation with a floating [+back] autosegment. We illustrate this in (4b):

(4b)



The essential difference between harmonic and disharmonic stems is that in the former all vowels agree in backness, whereas in the latter that is not the case. To capture this property of disharmonic stems we postulate that the last or only harmonizing vowel in a disharmonic stem is *linked* to an [αback] autosegment:

(4c)



Disharmonic stems with a linked [-back] autosegment may take either front or back suffixes. Thus, the elative of the first word in [4c] is

(4d) *afääristä* or *afäärista*

On the other hand, disharmonic stems with linked [+back] autosegment take always [+back] suffixes, never [-back]. Thus, we find no *olympialaisissähän* but only *olympialaisissahan*. We think that this state of affairs is due to the existence of two dialects: one of which is more conservative than the other. In the more conservative dialect there is a rule that places a floating [+back] autosegment to the right of a linked [+back] autosegment. In the less conservative dialect, the rule introduces a [+back] autosegment to the right of a linked autosegment regardless of whether it is [+back] or [-back]. The alternative pronunciations of suffiexes after disharmonic stems with a linked vowel that is [-back] must then be attributed to the fact that speakers switch from the more to the less conservative dialect and back.

2. DIRECTIONAL HARMONY ILLUSTRATED

Directional harmony differs from dominant harmony in several essential respects. First, directional harmony propagates in the same direction – left-to-right or right-to-left – in all words, whereas as we have seen above dominant harmony may spread in one direction in one word, in the opposite direction in another word, and in both directions simultaneously in a third

word. As a consequence of the uni-directional character of directional harmony the location of the triggering element – sequence-initial or sequence-final – is determined automatically by the direction of propagation. Hence, directional harmony is triggered exclusively by elements that are terminal – i.e., initial or final – in the harmonizing sequence, whereas in dominant harmony the position of the triggering element in the sequence is of no moment. Finally, in dominant harmony a distinction is made between triggering and opaque elements. No such distinction is made in the case of directional harmony: all triggering elements are opaque, and each opaque element induces a harmony of its own. Moreover, the terminal element in a word – the initial element in the case of left-to-right harmony, and the final element in the case of right-to-left harmony –always triggers harmony of its own (see (5bii)).

A simple example of these properties is provided by the rounding harmony of modern Turkish[3]. As shown in (5ai), in Turkish a string of consecutive high vowels agrees in rounding either with an immediately preceding non-high vowel or, in the absence of a non-high vowel, with the word-initial vowel in the word:

(5a) i. gid-iyor-um "I am going" agir-las-iyor-mus "it was said to be getting heavy, serious"
gurur-un-uz "your pride" kiz-im-iz "our girl"

Another example of directional harmony is provided by Navaho. In this language the feature [anterior] in coronal affricates and continuants is determined by the right-most coronal affricate or continuant in the word: where the latter is [+anterior] (alveolar) so are all those to its left; when it is [-anterior] (palatal), the same is true of the other coronal affricates and continuants in the word. We illustrate this in (5aii) with the Navaho morphemes /ǰi/ "he (4.p.)" and the perfective morpheme /z/ (examples from Sapir and Hoijer (1967)

(5a) ii. ǰi-di-baah "he (4.p.) starts off to war"
ji-siii "he (4.p.) steams it"
ji-z-ti "he (4.p.) is lying"
ǰi-ž-γiiš "he (4.p.) is stooped over"

It is, in principle, possible to characterize directional harmony processes

with the same descriptive devices as those employed for the characterization of dominant harmony processes. However, the complications which this course of action frequently entails (for some examples see Sec. 3) are such as to raise questions about the validity of this approach: are these types of harmony phenomena in reality special instances of a single process, or are the similarities between the phenomena more superficial than might appear at first sight? Questions such as these have led us to explore the possibility that the two types of harmony processes are based on essentially different linguistic mechanisms, both of which are provided by universal grammar. Specifically, we propose that whereas for dominant harmony languages make use of the mechanism sketched above which is essentially an adaptation of the mechanism employed in various tonal processes; for directional harmony, languages make use of a mechanism, to be outlined below, which is an adaptation of the metrical structure mechanism that is otherwise employed in various stress and accent systems.

Fundamental to metrical phonology is the idea that two adjacent elements are gathered into a single unit by erecting a branching structure over them:

In the branching structures of interest here it will always be the case that one of the two branches (the left branch or the right branch) is superordinate or dominant over the other. A given process – e.g., stress distribution or rounding harmony in a particular language – employs branching structure of only a single type of superordination or dominance.

Conditions of various sorts may be imposed on the nodes A and B that are connected into a single binary branching structure. E.g., it may be required that A and B must dominate a [+syl] slot or that A and B may not dominate [-syl] slots (cf. 1f). In the former case, tree construction would be limited to the single binary branching structure illustrated above. If the latter condition were imposed instead, a greater variety of trees would be admitted, as shall be illustrated directly.

Among the conditions to be imposed on branching structures perhaps the most interesting for our purposes is (5b):

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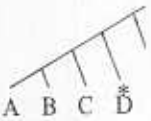

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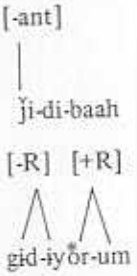

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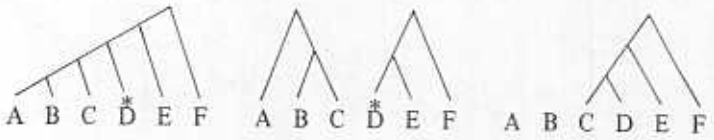
not dominate a node that is branching or that is specially marked by being linked to an autosegment on a separate tier.

ii. All elements in a string must be incorporated into branching structures.

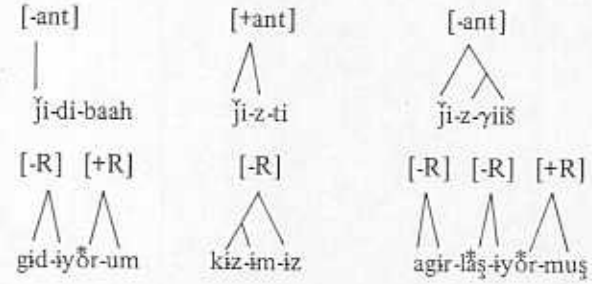
Among the consequences of the above conditions the following are worthy of special note: All trees are uniquely left- (resp. right-) branching. Trees such as those in (5c) are ruled out as a violation of (5b), where the asterisk above a particular element indicates that the element in question is marked:

(5c)



As these properties of trees have been extensively discussed in the literature on metrical phonology, we will not dwell on them here further. Additional information about these matters can be found in the first volume of M.I.T. Working Papers in Linguistics (K. Safir, ed. (1979)) and in B. Hayes' (1980) dissertation. There is one respect in which stress trees differ from harmony trees, and that is with respect to the labelling of their nodes. In stress trees, such as those of English, only the designated terminal node is marked [+stress], all other nodes are labelled [-stress]. In harmony trees, by contrast, all terminal nodes are labelled the same as the designated terminal node. Following a suggestion of J.-R. Vergnaud (1975), we propose that the feature specification of the designated terminal node is copied by a rule on to the root of the tree and percolates downward from there to all terminal nodes of the tree. We illustrate this with examples from Navaho and Turkish in (5d):

(5d)



(The asterisks indicate that the vowels in question are marked.)

It is important to note that a root labelling rule of this kind must always *copy* feature specifications from a slot in the core; it cannot assign an arbitrary feature specification to the root. This is a significant limitation on the power of the directional harmony mechanism.

In addition to opaque elements like those above which block and trigger harmony, there appear to exist elements that only block, but do not trigger any harmony of their own. A particularly interesting example is provided by rounding harmony in Khalkha Mongolian, which has been studied in a recent paper by Steriade (1979). Like Turkish, Mongolian has both backness and rounding harmony, and as in the case of Turkish we shall restrict our discussion to rounding harmony alone. We summarize in (6a) the main facts of interest.

(6a)

i. Non high vowels undergo and trigger RH:
ot-ox "to keep watch on"; org-ox "to raise"; avr-ax "to save"; hem-ex "to add".

ii. High vowels do not trigger RH:
düü-gees "from the younger brother"; gur-ba "three".

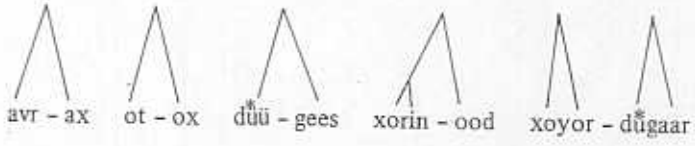
iii. High vowels do not undergo RH:
dag-uul "to cause to follow"; med-uul "to cause to know"; morin "horse".

iv. /i/ does not block RH:
oril-ox "to weep"; xorin-ood "by twenties"; morin-oor "horse" (inst. sg.).

v. Round high vowels block RH:
xoyor-dugaar "second"; yos-dugeer "ninth"; boodg-uul-ax "to hinder".

In order to account for these facts on the assumption that they are instances of directional harmony, we stipulate that [+high, +round] vowels are opaque, for they interrupt rounding harmony. In the case of directional trees this means that each opaque vowel will initiate a separate tree, as illustrated in (6b). Moreover, since harmony here propagates from left to right, the trees to be constructed must be left-dominant.

(6b)



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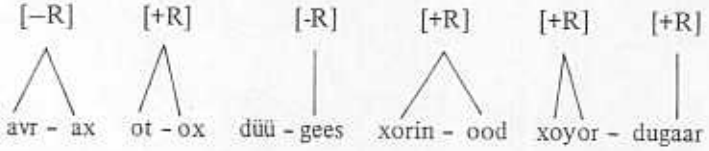
contrast before obstrue

(7a)
o[t]ozera
o[t]strasti
o[t]pragi
o[t]ptic "i
o[d]banka
o[d]grexa
o[d]bdenij

A possible way of deal
is an instance of direc
is opaque. We can then

We propose that the algorithm for the construction of directional harmony trees admits a second step in which certain branches in the tree are pruned while leaving the remaining structures intact. In the cases of Mongolian, the nodes to be pruned are all [+high] vowels. This produces the trees in (6c):

(6c)



The feature specification of the trees is supplied by the root labelling rule which copies the rounding specification of the designated (i.e., left-most or only) node of the tree. This completes the derivation.

We complete the illustration of the directional harmony algorithm by a discussion of voicing assimilation in Russian. As will be seen below, this phenomenon, whose full complexity has been brought out clearly only in the last decade thanks to the pioneering studies of A. A. Reformatskij (1971) and of Roman Jakobson (1978), can readily be accounted for if treated as an instance of directional harmony with the devices sketched above.

Almost every grammar of Russian includes the information that in obstruent clusters voicing is governed by the last obstruent in the cluster. This distribution of voicing is illustrated in (7a) with the prepositions *ot* "from" and *bez* "without" which contrast in voicing before vowels but lose the contrast before obstruents:

(7a)

o[t]ozera "from a lake"	be[z]ozera "without a lake"
o[t]strasti "from passion"	be[s]strasti "without passion"
o[t]pragi "from Prague"	be[s]pragi "without Prague"
o[t]ptic "from birds"	be[s]ptic "without birds"
o[d]banka "from a bank"	be[z]banka "without a bank"
o[d]grexa "from a sin"	be[z]grexa "without sin"
o[d]bdenija "from a vigil"	be[z]bdenija "without a vigil"

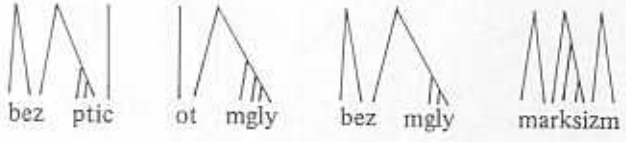
A possible way of dealing with these facts would be by stipulating that this is an instance of directional harmony where the last obstruent in a cluster is opaque. We can then construct right dominant trees illustrated below:

In order to make this proposal work it is necessary to stipulate that the voicing autosegments can be linked only with obstruents and that obstruents are opaque unless followed by another obstruent. This rather complex stipulation, however, does not cover the facts completely. It will have to be supplemented by additional stipulations in order to account for the distribution of voicing in consonant clusters containing both obstruents and sonorants as illustrated in (7b):

(7b)		
	o[t]nravov "from morals"	be[z]nravov "without morals"
	o[t]Mcenska "from Mtsensk"	be[s]Mcenska "without Mtsensk"
	o[t]mstitel'nosti "from vindictiveness"	be[s]mstitel'nosti "without vindictiveness"
	o[d]mgly "from fog"	be[z]mgly "without fog"
	o[d]lguni "from the liar"	be[z]lguni "without the liar"

In these clusters not all presonorant obstruents are opaque. For example, in *o[d]mgly* and *be[z]mgly* the *g* preceding the *l* is opaque, whereas the obstruents preceding the sonorant *m* are not opaque as shown by the fact that they assimilate voicing from the *g*. Thus, at the very least we would have to amend our stipulation to state that obstruents are opaque when followed by a sequence of any number of sonorants terminating with a vowel or a word boundary. In addition to being unwieldy this revised formulation fails to do justice to the actual process. As noted by Jakobson (1978) what actually transpires is that in consonant clusters voicing propagates across sonorants; these sonorants are simply disregarded. Since the solution sketched above cannot readily express this state of affairs, there is reason to consider an alternative.

As an alternative we propose to follow the two step procedure in tree construction illustrated above with regard to rounding harmony in Mongolian. Specifically, we propose that in the first stage of tree construction all segments be taken into account and that vowels be regarded as opaque; the trees to be constructed on these sequences are right-dominant as illustrated below. Note that word final phonemes – consonants as well as vowels – are opaque by the convention requiring that every phoneme in the string be incorporated into a foot.



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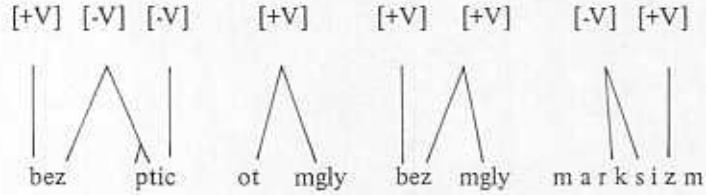
In the second stage of tree construction branches terminating in a sonorant are filtered out yielding the trees:

At this point we apply the rule copying on to the root of the tree the voicing feature of the designated (in this case, right-most) element of the tree, producing thereby the correct outputs as shown below:



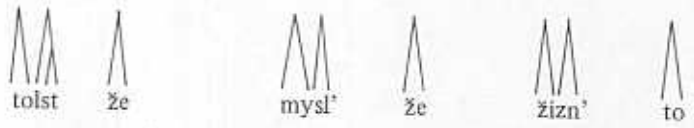
Consider next the treatment of voicing in position at the end of the word. We illustrate in (7c) the facts both in absolute final position and before enclitics.

(7c)

zve[zd]a "star"	tol[st]a "stout"	ži[zn']i "life"	my[sl']i "thought"
zve[st]	tol[st]	ži[zn']	my[sl']
zve[st]li	tol[st]li	ži[zn']li	my[sl']li
zve[st]to	tol[st]to	ži[zn']to	my[sl']to
zve[zd]že	tol[zd]že	ži[zn']že	my[sl']že

Like German, Russian devoices obstruents in word final position. The fact that an entire obstruent cluster devoices word finally, as shown by forms such as *zve*[*st*] from underlying zve[*zd*], indicates that the rule devoicing word final obstruents must be ordered before the rule that copies the voicing specification on to the root of the tree. Since only word final obstruents are devoiced, the [z] in *ži*[*zn'*] is unaffected by the devoicing rule.

The examples in the last two rows of (7c) show that enclitics affect the voicing in word final clusters if these are made up entirely of obstruents, but not if they include sonorants; cf., e.g., *tol*[*zd*]*že* with *my*[*sl'*]*že* or *ži*[*zn'*]*to*. Since word final phonemes are opaque the word final cluster is not in the same tree as the enclitic, as illustrated below:



This produces the correct results for words ending in sonorants, but it fails in the case of *tol*[*zd*]*že*. What is needed here is a special rule that incorporates two adjacent obstruents into a single tree. This rule affects

because in the latter the obstruents do not adjoin. If we assume that the rule of foot incorporation precedes the rule copying the voicing specification on to the root of the tree, the facts noted above are fully accounted for.

The behavior of word final sonorants sheds light on a very interesting phonetic observation made by A. A. Reformatskij. Reformatskij noticed that in his speech and in that of other speakers of the Moscow dialect, obstruents preserved voicing in word final position before underlying /v/, in spite of the fact that phonetically word final /v/ is devoiced.

(7d)	ja[zv]a "wound"	tre[zv]a "sober"	xoru[gv']i "banner"
	ja[zf]	tre[zf]	xoru[gf']

These voiced-voiceless obstruents clusters are otherwise totally unprecedented in Russian. They would, of course, be fully explained if the Russian /v/ were to be regarded as the underlying glide /w/. Being a sonorant, word final /w/ is pruned from the word final foot:

A subsequent rule turns /w/ into the obstruent /v/. If this rule is ordered before word final devoicing we obtain the correct output [jazf].

There are very good reasons for treating /v/ as an underlying glide. First, like glides /v/ deletes before consonants whereas obstruents are preserved:

(7e)	znaj-u	"I k
	zna-la	"I k

Secondly, unlike obstru
obstruents:

(7f)	tvoj	"you
	dva	"two

These facts fall out dir
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There is yet one fina
of /v/ inside obstruent
are transparent to voici
like sonorants; i.e., wo
preceding obstruent; w
harmony.

(7g)	o[dvd]ovy	
	o[tft]oroj	
	tre[zft]o "s	

The rules developed
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be[svt]oroj

The obvious move here
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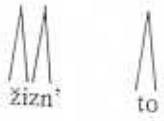

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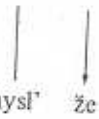

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If this rule is ordered
t [jazf].
nderlying glide. First,
ruents are preserved:

(7e)

znaj-u	"I know"	nes-u	"I carry"	živ-u	"I live"
zna-la	"I know" f.s.	nes-la	"carried"	ži-la	"lived"

Secondly, unlike obstruents /v/ does not trigger voicing harmony in preceding obstruents:

(7f)

tvoj	"your"	o[t]vas	"from you"
dva	"two"	be[z]vas	"without you"

These facts fall out directly if /v/ is represented underlyingly as a glide, and is turned into an obstruent by a special rule that precedes word final devoicing and the labelling of roots of voicing harmony trees.

There is yet one final set of facts to be considered and that is that behavior of /v/ inside obstruent clusters. As observed by Jakobson (1956) such /v/ are transparent to voicing assimilation; they function in this respect precisely like sonorants; i.e., word medially they allow voicing harmony to affect the preceding obstruent; word-finally, on the other hand, they block voicing harmony.

(7g)

o[dvd]ovy "from a widow"	be[zvd]ovy "without a window"
o[tft]oroj "from the second"	be[sft]oroj "without the second"
tre[zft]o "sober, though"	tre[zvž]e "sober, indeed"

The rules developed to this point account for the spread of voicing to obstruents in clusters containing /v/, they do not account fully for the distribution of voicing in /v/ itself. In particular, we have not accounted for the distribution of voicing in such examples as *be[sft]oroj* and *tre[zvž]e*. Given the rules developed above and the order: foot incorporation

$w \rightarrow v$

word final obstruent devoicing

copy feature on root

the forms just quoted would be expected to surface as

be[svt]oroj tre[zfž]e

The obvious move here is to add a rule affecting only /v/ and /f/ and having these assimilate from a following obstruent

$$[-son, +lab, +cont] \longrightarrow [\alpha voiced] / \_\_ \begin{bmatrix} \alpha voiced \\ -son \end{bmatrix}$$

3. THE TWO HARMONY PROCESSES COMPARED

The facts of the different harmony processes in the preceding sections do not force us to adopt the particular solution that was presented. It is, for example, not impossible to describe the consonant harmony in Navaho as an instance of dominant harmony, or the rounding harmony in Finnish as an instance of directional harmony. In this section we compare alternative treatments of some of the examples discussed above in order to make explicit the basis on which choices between alternatives are made.

Consider first the Navaho facts given in (5a). The solution advanced in section 2 was based on the assumption that these are instances of directional harmony. This solution required us to stipulate the facts in (8a-i):

(8a) i. Terminal nodes of tree: [+coronal] continuants and affricates
Direction of propagation: right to left
Harmony process: [αanterior] is copied by rule on to root of tree (from designated terminal element).

We compare this information with the information that would have to be stipulated if the Navaho facts were treated as instances of dominant harmony:

(8a) ii. Terminal nodes of tree: [+coronal] continuants and affricates
Harmony process: [αanterior] is copied by rule from right-most [+coronal] continuant or affricate in the word onto separate autosegmental tier.

In comparing these two solutions it is to be noted that given the mechanism for directional harmony developed above the stipulations in (8a-i) are the minimum necessary to construct a directional harmony tree. By contrast, the stipulations in (8a–ii) are not the minimum necessary to specify a dominant harmony process. In particular, a rule stipulating that the floating autosegment is always [+anterior] or [-anterior] is surely simpler than the stipulation in (8a–ii). Moreover, unlike the directional harmony mechanism the dominant harmony mechanism does not select the right-most unit in a string in preference to any other unit. Given the dominant harmony mechanism it would be equally simple to select the unit preceding a voiced coronal or following an affricate. In view of this it seems fair to conclude that the facts of Navaho are more correctly treated as instance of directional, rather than of dominant harmony.

The opposite conclusion emerges in the case of backness harmony in

Finnish (cf. (4b) an
backness harmony is
to stipulate the follo

(8b) i. Termin
Opaque
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Moreover, in the mo
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(8b) ii. Termina
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Consider next the
in (6a). The informati
facts as a case of direct

(8c) i. Terminal
Opaque:
Direction

Finnish (cf. (4b) and (4c)). It was assumed in section 1 above that Finnish backness harmony is an instance of dominant harmony, and this required us to stipulate the following information.

(8b) i. Terminal nodes: [+low] or [+round] vowels
Opaque: right-most [+low] or [+round] vowel in disharmonic stems
Harmony process: floating [+back] is supplied either lexically, or introduced by rule to the right of an opaque (linked) [+back] autosegment

Moreover, in the more conservative dialect the rule introducing the [+back] autosegment applies only if the opaque vowel of the disharmonic stem is also [+back], whereas in the less conservative dialect, it suffices that the stem is disharmonic for the floating [+back] autosegment to be introduced.

We compare the preceding with the information required if the Finnish facts were to be viewed as an instance of directional harmony:

(8b) ii. Terminal nodes: [+low] or [+round] vowels
Direction of propagation: left to right
Opaque: [+low] and [+back] vowels in disharmonic stems
Harmony process: [back] copied by rule on to root of trees

For the more conservative dialect where suffixes are [+back] only after disharmonic stems whose last harmonizing vowel is [+back], nothing further needs to be stipulated. For the less conservative dialect, however, where suffixes are [+back] after all disharmonic stems, a rule of considrable complexity is required. This rule will have to render opaque the first suffix with a harmonizing vowel by supplying it with a linked [+back] autosegment. The need for this kind of a rule is a direct consequence of the decision to treat the Finnish facts as instances of directional, rather than dominant harmony, and it suggests that it would be more correct to view the Finnish facts as instances of dominant harmony as was done in section 1 above.

Consider next the rounding harmony facts of Khalkha Mongolian quoted in (6a). The information that has to be stipulated for a description of these facts as a case of directional harmony is summarized in (8c-i):

(8c) i. Terminal nodes: all vowels in the word
Opaque: [+high, +round] vowels
Direction of propagation: left to right

Pruning rule: eliminate [+high] nodes from tree
Harmony process: [αround] is copied by rule on to root of tree

The preceding should be compared with a treatment of the same facts as instances of dominant harmony. The information that has to be supplied in such an account is given in (8c-ii):

(8c) ii. Terminal nodes: [-high] and [+high, +round] vowels
Opaque: [+high, +round] vowel
Harmony process: [+round] is introduced by rule as a floating autosegment if stem begins with a [+round, -high] vowel.

The two accounts differ primarily with regard to their characterization of the harmony process. In the "dominant" account the introduction of the floating [+round] autosegment requires special reference to the fact that the left-most vowel in the stem is [+round, -high]. In the "directional" account there is no need to focus special attention on the left-most vowel of the stem, since once the direction of propagation has been stipulated as left to right, the left-most vowel is the only one from which features can be copied on to the root of the tree. Thus, the extra information that must be included in the "dominant" account of Mongolian rounding harmony is not due to the complexity of the phenomenon, but rather to the (incorrect) decision to describe Mongolian rounding harmony as an instance of dominant harmony.

Our final and perhaps most telling example is the treatment of voicing assimilation in Russian. The facts of interest here were given in (7a) to (7g) above where also a "directional" treatment of the phenomena was presented. The information that must be stipulated for this treatment is summarized in (8d-i):

(8d) i. Terminal nodes: all slots in phonological core
Opaque: vowels
Direction of propagation: right to left
Pruning rule: eliminate [+sonorant] nodes from tree
Harmony process: [αvoiced] is copied by rule on to root of tree

We omit from consideration here the special treatment of obstruents in position before enclitics and the complications introduced by the behavior of /v/ because these do not provide evidence for choosing between the two solutions being compared. These facts apart, the Russian voicing assimilation can be treated as an instance of dominant harmony provided that the information in (8d-ii) is stipulated:

(8d) ii. Terminal n
Opaque: o
with a vow
Harmony
of an (op

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[2] Loos (p. 175) quotes the
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Hall, B. et al.: 1974, 'Nilo-
Afrika und Übersee 57,
Halle, M. and J.-R. Vergnau
Research 1, 83–105.

(8d) ii. Terminal nodes: obstruents
Opaque: obstruent followed by a sequence of sonorants ending with a vowel or a word boundary
Harmony process: a floating [αvoiced] is introduced to the left of an (opaque) [αvoiced] autosegment linked to an obstruent

It is self-evident that the information in (8d-ii) is significantly more complex than the information in (8d-i). The specification of the opaque elements in (8d-ii) is particularly unwieldy and unnatural. Further complexity is added by the rule describing the harmony process in (8d-ii). We conclude from this that Russian voicing assimilation is an instance of directional, rather than of dominant harmony.

NOTES

* The material presented in this study is to be included in a longer work on metrical phonology which has been in preparation for some time, see Vergnaud and Halle (1979) and Halle and Vergnaud (1980). We are grateful to G. N. Clements, L. Hyman, P. Kiparsky, W. Poser, D. Steriade and M. L. Zubizarreta for comments and criticisms. This work was supported in part by National Institutes of Mental Health Grant #5 PO 1 MH 13990–14.

[1] In a paper now in preparation Paul Kiparsky develops an alternative treatment of the processes discussed here. Although Kiparsky's primary concerns are somewhat different from those that are central here, his work may lead to a revision of the proposals made below.

[2] Loos (p. 175) quotes these forms without nasalization; his discussion, however, makes it all but certain that the forms are actualized with nasalization as indicated.

[3] As is well known, Turkish has both rounding and backness harmony, and these two types of harmony are subject to different principles. The remarks here are limited to rounding harmony.

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THE "EPISTEMI
AND ITS RELE
II

1. The sentences in (
studied, is quite comr
the "epistemic dative'

(1) (a) Je lui
ieved
(b) Je lui
(c) Le m
docto
(d) Leo
Princ
interp

These sentences seem

(2) (a) Je cr
lieved
(b) Je trc
much
(c) Le m
(The
(d) Leo
interp
Machi

A by no means exl
(1) and the sentential

(3) accorder
(believe),
imaginer
prédire (p
(pretend),

W. Klein and W. Levelt (e