Feature Geometry and Feature Spreading
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Morris Halle

Feature Geometry and Feature Spreading

1 Introduction

Since the publication of Clements's (1985) pioneering paper on the geometry of phonological features a consensus has emerged among many investigators that the complexes of features that make up the phonemes of a language do not form a simple list, but possess a hierarchical structure represented geometrically in the now familiar tree of the kind illustrated in (1), on page 2.[1] A major argument in support of this proposal was the observation that only a small fraction of the logically possible pairs, triplets, . . . , *n*-tuples of features have been shown to figure in actual phonological rules. For example, there are no phonological rules that involve groups of phonemes defined by such feature pairs as [−back, −continuant], [+strident, −round], or [−low, +stiff vocal folds]. The feature tree takes formal account of this observation by splitting the universal list of features into mutually exclusive subsets of features and grouping the subsets into higher-order sets. If it is further assumed that only these feature sets can be referred to by the rules and principles of the phonology, then other feature sets—for example, the feature pair [−back, −continuant] and the others just cited—are excluded from figuring in the phonology.

Sagey (1986) examined feature sets that function in the phonology of different languages and showed that these functionally defined sets also share important phonetic characteristics. In particular, Sagey showed that the features in the lowest sets defined in the tree are executed by the same articulator. For example, the features [anterior] and [distributed] are both executed by the tongue blade, whereas [stiff vocal folds], [slack vocal folds], [spread glottis], and [constricted glottis] are executed by the larynx. Thus,

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[1] The feature tree in (1) differs in a number of respects from that in Clements 1985 and Sagey 1986. These differences are discussed at various places in the rest of the article.

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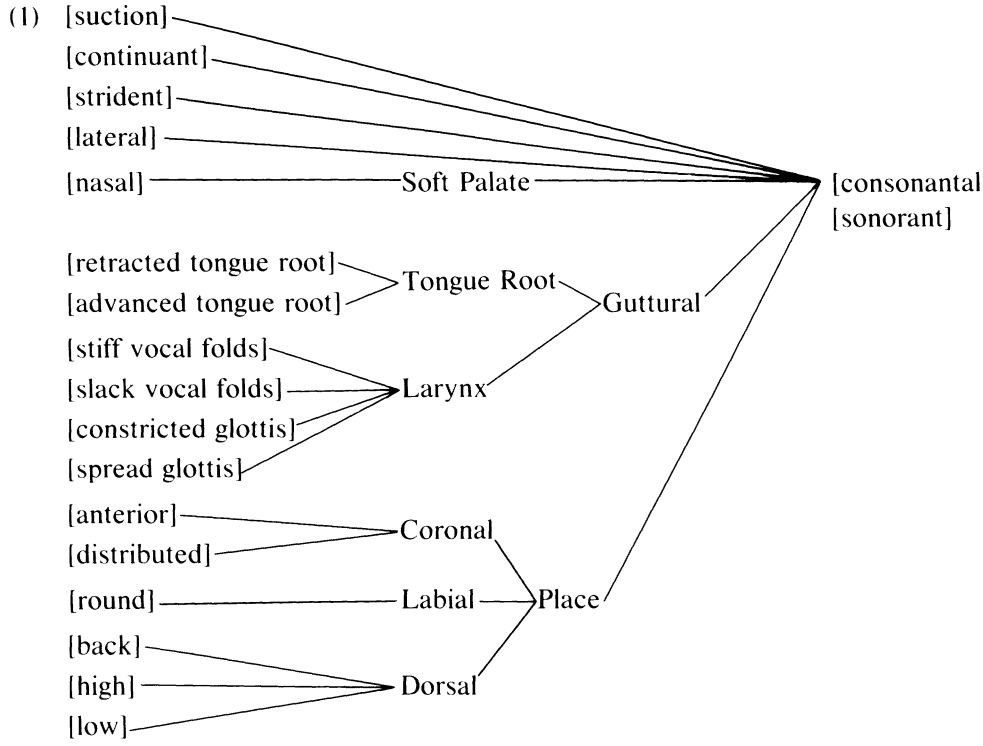
(1)



the feature sets in (1) simultaneously reflect two distinct aspects of features: the anatomical mechanism by which they are phonetically implemented and the fact that they function as units in rules. This convergence clearly is a result of considerable interest. It suggests that all functional feature groupings have an anatomical basis. I adopt this proposition as one of my working hypotheses, and much of what follows is an extended argument in support of it.

As noted in Halle and Stevens 1991, the special role of articulators has not been fully recognized in the study of speech sounds. The phonetic actualization of a feature is an action performed by an articulator. Since the actions of interest here must eventuate in distinct acoustic signals, it is plausible to define an *articulator* as a part of the vocal tract anatomy capable of changing the geometry of the cavity or determining the manner in which it is excited, for these are the only ways in which the acoustic output of the vocal tract can be affected. The only vocal tract components that meet this condition are the lips, the soft palate, the larynx (more accurately, the glottis), the tongue root, the tongue body, and the tongue blade. This implies that from a phonetic point of view, all speech is the result of actions by one or more of these six articulators. It is an indication of the underdeveloped state of phonetic theory that this proposition is rarely, if ever, discussed in phonetics textbooks.

Features differ with respect to whether or not they have a dedicated articulator. On the one hand, there are features such as [nasal], [back], or [anterior] that are always executed by a given articulator. On the other hand, there are features such as [continuant] or [lateral] (see Ladefoged and Maddieson 1986) that may be executed by several different articulators. Adopting the terminology in Halle and Stevens 1991, I shall refer here to the former as *articulator-bound* features and to the latter as *articulator-free* features.

This purely anatomical distinction among features is paralleled by a distinction with respect to their behavior in assimilation processes. McCarthy (1988) has observed that unlike articulator-bound features, two or more articulator-free features assimilate together only in cases of total assimilation. Moreover, it appears that the articulator-free features [consonantal] and [sonorant] never assimilate singly, but only when there is total assimilation. Other articulator-free features—for example, [continuant]—assimilate under both conditions. As McCarthy suggests, this difference can be readily captured in the geometry of the feature tree by locating the former two features at the root node and by treating the rest of the articulator-free features as direct dependents of the root node (see (1)).

As noted above, articulator-bound features executed by a given articulator are grouped together in the feature tree (1). If this grouping is seen as the reflection of the fact that each articulator-bound feature has its own dedicated articulator, the absence of such groupings of articulator-free features can be seen as a reflection of the anatomical fact that articulator-free features lack dedicated articulators. Thus, once again the anatomical properties of features and their behavior in assimilatory processes converge.

The distinction between articulator-free and articulator-bound features has significant consequences for our conception of the nature of speech sounds. Although it is redundant to specify the articulator for an articulator-bound feature, it is essential to do so for every articulator-free feature, because without this information the feature cannot be executed. In what follows, the articulator that executes an articulator-free feature is referred to as the *designated* articulator.[2]

I have proposed (Halle 1992) that the feature [consonantal] must be included in the representation of every phoneme. Since [consonantal] is an articulator-free feature, a direct consequence of this proposal is that every phoneme must have its own designated articulator. Therefore, in addition to a list of (articulator-bound) features, the phonetic representation of every speech sound must mention the designated articulators of the phoneme, that is, the articulator that executes the articulator-free feature(s) of the phoneme. In section 2.1 I attempt to show that implementation of this purely formal requirement in the representation of clicks leads to a better understanding of these well-known cruxes of phonetics.

[2] The *designated articulator* is a lineal descendent of Sagey's *major articulator*. It differs from the latter in a number of respects, of which the most important is the requirement that every phoneme must have a designated articulator (see below). Sagey's device of the pointer is utilized here to indicate the designated articulator in a feature tree.

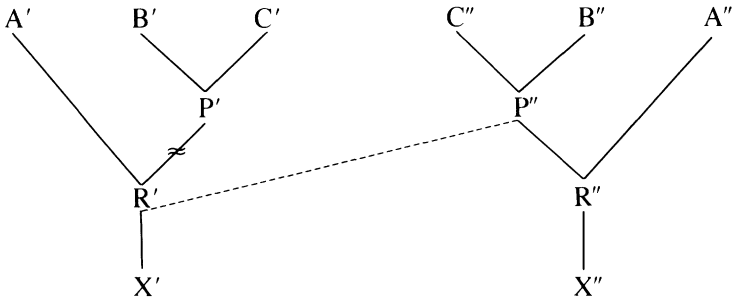
In (1) the articulator-bound features are grouped together under the different articulators that execute them. Thus, [low], [high], and [back] are located under the Dorsal (tongue body) node, [anterior] and [distributed] are located under the Coronal (tongue blade) node, and so on. However, these are not the only groupings of features that play a role in phonology. For example, in many languages nasal consonants in syllable coda position assimilate "Place" from the onset consonant of the following syllable. Thus, in Sudanese Arabic the Coronal nasal [n] becomes [m] before the Labial [b], and [ŋ] before the Dorsal [k x]. Before Coronal consonants, however, it has two reflexes: before the [−anterior] consonants [š ǰ] it surfaces as the [−anterior] nasal [ñ], and before the [+anterior] consonants [s z] it surfaces as the [+anterior] nasal [n]. (Data from Kenstowicz 1994:158.) In sum, this assimilation process involves the three articulators together with the features assigned to them. In the feature tree (1) the Place node dominates the three articulators in question. The information involved in the above assimilation process is therefore that available at the Place node, and this fact provides the functional motivation for the establishment of the node. The Place node also has a straightforward anatomical motivation: it combines three articulators that are adjacent to one another.

Though the matter has not been much discussed in the literature, the Labial, Coronal, and Dorsal articulators are traditionally grouped together under the Place node, whereas the Soft Palate and the Larynx are not treated as belonging under the Place node. The sixth articulator, the Tongue Root, is usually assumed to be a dependent of the Place node. However, functional evidence presented in Halle 1989 and restated below leads me to propose that the Tongue Root should be grouped with the Larynx articulator under a common node labeled Guttural. A plausible anatomical motivation for this grouping of the Larynx and Tongue Root articulators together under the Guttural node is the fact that they are next to each other in the vocal tract.

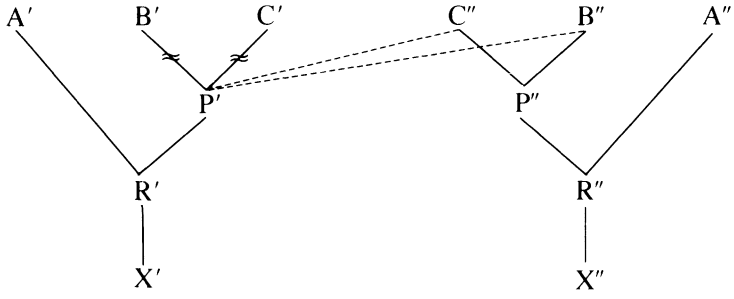
The feature organization sketched in the preceding paragraphs and illustrated graphically in (1) is discussed in greater detail in sections 2 and 3. In sections 4 and 5 this feature organization is tested by examining its role in the formalization of assimilatory processes in a variety of languages. As noted above, Clements (1985) has proposed that in order for several features to be assimilated simultaneously, they must be dominated by a single node in the universal feature tree. As a consequence, it has become common practice among phonologists to represent assimilations of groups of features by linking a nonterminal node of one feature tree to the immediately dominating node in an adjacent tree, as illustrated in (2). As shown in (3), precisely the same phonetic effects can be notated by spreading the terminal nodes that are dominated by the nonterminal node spread in the diagram in (2). Evidence reviewed in section 4 supports the latter notation over the former as the more accurate representation of the facts. Clements's proposal can readily be reformulated in the new notation. In the new notation the proposal allows phonological rules to refer to groups of features only if they are dominated by a single nonterminal node in the tree.

There are numerous cases in the literature that appear to violate Clements's proposition that only features dominated by a single nonterminal node in the tree may be assimi-

(2)



(3)



lated. For example, in the Wikchamni dialect Yokuts (see Odden 1991) the features [round] and [back] assimilate together without also affecting the feature [high]. Facts such as these have been taken to show that the anatomically plausible tree (1) is incorrect and must be replaced with a tree in which the nodes reflect nothing but functional commonalities.

This is, of course, not the only reaction possible to apparent counterexamples of this kind. A plausible alternative is to search for reasons that might explain the deviant behavior. In sections 4 and 5 I adopt this alternative and defend the feature tree (1). Crucial to this defense is the assumption that only terminal nodes can be spread by assimilation rules and that the multiple linkings of nodes resulting from such rules may not violate the Line-Crossing Constraint proposed by Sagey (1986:chap. 5, 1988). In the light of this principle the Yokuts vowel harmony rule cited above can be stated as spreading the natural set of features dominated by the Place node; but because the harmony process is restricted to sequences of vowels that are identical with respect to the feature [high], this feature is automatically exempt from the rule. As a result, although the features mentioned in the rule constitute a natural class, the conventions on rule application prevent the entire set of features from being spread and the illusion is created that the features spread by the rule do not make up an anatomically motivated set. A number of instances of this type are discussed in sections 4 and 5.1.

In section 5.2 I discuss a proposal to split the Dorsal node into two separate nodes, of which one is restricted to vowels and the other to consonants. I argue that the phenomena of Javanese that supposedly motivate the splitting of the Dorsal node must not be expressed by a formal rule of the phonology. If these counterarguments are valid, there

is no need for the proposed node split and no basis for questioning the anatomically motivated feature tree (1).

2 The Articulator-Free Features

As noted in section 1, we distinguish two kinds of features: articulator-bound (AB) and articulator-free (AF). The two sets of features differ in that an AF feature may be executed by a number of different articulators, whereas each AB feature is associated with a specific, dedicated articulator. For example, the AF feature [continuant] can be executed by the lips, the tongue blade, or the tongue body; by contrast, the AB feature [nasal] is executed only by the soft palate, and the feature [anterior] is executed only by the tongue blade. Because of this fact it is essential to specify for every AF feature the designated articulator that executes it.

The set of AF features in the universal feature set consists of {[consonantal], [sonorant], [continuant], [strident], [lateral], [suction] (click)}. The evidence for the AF nature of each of these six features is briefly reviewed in the paragraphs below.

The AF nature of [continuant] is straightforwardly evidenced by the fact that in most languages there are several series of obstruents distinguished by the feature [±continuant], where this feature is executed by different articulators: Labial ([p b f v]), Coronal ([t d s z]), Dorsal ([k g x]).

The feature [strident] serves to distinguish bilabial from labiodental continuants in Ewe (see Ladefoged 1964:53), and the interdental from the alveolar Coronal continuants in English (e.g., *think* vs. *sink*). It is not clear whether [strident] can also be distinctive for Dorsal obstruents, but the noted presence of the contrast in Labial and in Coronal obstruents suffices to establish [strident] as an AF feature.

The AF nature of the [lateral] feature is established by evidence such as that from Waghi, a language of New Guinea, where, as reported by Ladefoged and Maddieson (1986), in addition to laminal and apical laterals—that is, laterals executed by the Coronal articulator—there are also laterals executed by the Dorsal articulator (tongue body). They report that

> it was possible to see that the tongue was bunched up in [the] back of the mouth with the tip retracted from the lower front teeth. The body of the tongue was visibly narrowed in the central region. . . . The only articulatory contact was in the back of the velar region in much the same position as for a velar stop and, according to the speaker, air escaped around both sides of this contact in the region of the back molars. (p. 105)

It may be noted in this connection that the attempt by Blevins (see Levin 1988) to treat [lateral] as an AB Coronal (tongue blade) feature has been shown by Shaw (1991) to be untenable on phonological grounds totally unconnected to the articulatory implementation of the feature. For additional arguments against treating [lateral] as a Coronal feature, see Hegarty 1989. Also see below for additional discussion of [lateral].

The articulatory correlates of the feature [consonantal] are stated in (4).

(4) In producing a [+consonantal] phoneme, an articulator must make full or virtual contact with a stationary part of the vocal tract so as to create a cavity effectively closed at both ends; no such cavity must be created when [−consonantal] phonemes are produced.

The primary acoustic effect of creating a cavity closed at both ends is the lowering of the frequency of the first formant (lowest resonance), and this lowering of F1 is an important acoustic cue for a [+consonantal] phoneme. Since contact with a stationary portion of the vocal tract can be made by several articulators (e.g., the lips, the tongue blade, and the tongue body), [consonantal] is an AF feature.

The articulatory correlates of the feature [sonorant] are given in (5).

(5) In articulating [+sonorant] phonemes, no pressure must be allowed to build up inside the vocal tract; such pressure must be built up inside the vocal tract in articulating [−sonorant] phonemes. Pressure buildup is produced by an articulator making full or virtual contact with a stationary portion of the vocal tract while no side passage is opened in the vocal tract by dropping the tongue margins or lowering the Soft Palate.

From an articulatory point of view [−sonorant] phonemes are a subset of [+consonantal] phonemes. An immediate consequence of this fact is that like the feature [consonantal], the feature [sonorant] is AF. Further consequences of this partial overlap are discussed below.

At this point the question naturally arises whether it is ever the case that one AF feature is articulated by one articulator, while another AF feature is articulated by a different articulator. For example, does a phoneme exist in whose execution [+continuant] is articulated by the tongue body, whereas [+strident] is articulated by the lips? The general answer to this question is no, but the feature [suction] may constitute a partial exception to this regularity (see (9) below and discussion there).

As stated in (4), in the articulation of [+consonantal] phonemes, a cavity closed at both ends must be created inside the vocal tract. Such a cavity cannot be created by the three non-Place articulators. This is self-evident in the case of the Larynx (glottis) and Soft Palate articulators: neither of these can be positioned so as to create the requisite cavity. It is not clear whether the remaining articulator, the Tongue Root, is capable of making contact with the back wall of the lower pharynx. If physiologically possible, this contact plays no phonological role because the cavity that is created by this maneuver fails to produce the requisite acoustic effect on F1. Feature trees are therefore subject to the constraint (6).

(6) The designated articulator for [+consonantal] phonemes must be one of the three Place articulators, Labial, Dorsal, or Coronal.

In the light of (6), phonemes whose designated articulator is the Soft Palate, Tongue Root, or Larynx (glottis) must be [−consonantal].

In the phonemes discussed to this point the AF features are executed by a single designated articulator. As pointed out by Sagey (1986:209), there are sounds where the AF features are executed by two articulators simultaneously. As an example of this type of phoneme Sagey cites the stops of the West African language Nupe, illustrated in (7).

(7)

Labial	*Coronal*	*Dorsal*	*Labiodorsal*
p	t	k	kp
b	d	g	gb

In (7) each of the three Place articulators serves as designated articulator for one of the first three classes of stops. In view of restriction (6) no other articulator is left that can characterize the fourth class. The logic of the situation, as well as the phonetic facts, thus leads us to postulate that labiovelars are stops with two designated articulators, the Labial and the Dorsal.

Although several articulators are usually involved in the production of a given phoneme, not all of these function as designated articulator. For example, in the phonemes in (7) the Larynx is activated in addition to the Place articulator, since Nupe systematically distinguishes voiced and voiceless obstruents. However, the Larynx is not the designated articulator in these sounds; this role is played by the Place articulator(s) alone. An example of the need to distinguish the designated articulators from the other articulator involved in the production of a given phoneme is discussed in the next section.

2.1 The Articulator-Free Feature [suction]

The feature [suction] is the basic mechanism for clicks of all kinds. In order to produce the ingressive airstream that is characteristic of these consonants, the oral cavity is blocked off at both ends and the air within it is removed by suction. When the cavity is subsequently opened by releasing the anterior closure, the partial vacuum inside the cavity causes the ambient air to flow rapidly into it, thereby producing the characteristic click sound. It has therefore been generally assumed that clicks are stops produced with two designated articulators, of which one is Dorsal and the other either Coronal or Labial. They are thus assumed to resemble the Labiodorsals of Nupe in (7). This is the view advanced in Chomsky and Halle 1968, as well as in Sagey 1986 and in Maddieson and Ladefoged 1989.

I believe that a truer picture emerges if it is assumed that clicks have only a single designated articulator and that the second closure present in clicks is the phonetic implementation of the feature [+suction]. I was led to this conception by an observation made by Anthony Traill. In a lecture given at UCLA in January 1992 Traill suggested "that clicks are merely intense versions of pulmonic and glottalic consonants"—that is, that clicks differ from ordinary consonants only in being [+suction].

In the lecture Traill discussed clicks from the Bushman language !Xóõ. This language has five major classes of clicks, of which three have plosive releases and two have affricate releases. This is shown in (8), which reproduces the table in Traill 1992 captioned

"The Classification of Clicks according to the Properties of Spectral Emphasis and Abrupt Onset."

(8)	Bilabial	Dental	Lateral	Palatal	Alveolar
	⊙	|	‖	ǂ	!
Abrupt	−	−	−	+	+
High frequency	−	+	−	+	−

Since consonants characterized in the usual phonetic terminology as dental, lateral, palatal, and alveolar are executed by the Coronal articulator, the terms given in the top line of (8) imply that !Xóõ has four kinds of Coronal clicks but lacks clicks whose designated articulator is Dorsal. In this respect, then, the clicks would differ from ordinary "pulmonic and glottalic consonants," because the latter commonly include Dorsals in addition to Coronals and Labials.

Another interpretation of the click data is logically conceivable, however. As an alternative one might take as one's starting point Traill's suggestion that "clicks are merely intense versions of pulmonic and glottalic consonants." Perhaps the most stable characteristic of consonant systems is that they include sounds produced with each of the three Place articulators, Labial, Coronal, and Dorsal. Of the over three hundred languages surveyed in Maddieson 1984, all but one (Wichita) exhibit consonants of all three types. (Wichita has no Labial consonants.) The systematic absence of clicks whose designated articulator is Dorsal is therefore something of a problem for Traill's proposal that clicks are just special versions of pulmonic and glottalic consonants. If Traill's suggestion is correct, one might wonder whether the four series of non-Labial clicks in (8) are indeed all Coronal and whether some of them might instead be Dorsal.

As illustrated in figure 1, the frequency spectra of Dorsal consonants have marked energy peaks in the region between 1 and 2 kHz, whereas peaks in this frequency band are absent in the spectra of Labial and Coronal consonants. An examination of the click spectra in figure 2 shows that the alveolar and lateral clicks have marked energy peaks in the region between 1 and 2 kHz, whereas no energy peaks are found in this region in the spectra of the other three clicks. It is therefore quite plausible to suggest that the lateral and alveolar clicks are Dorsal, whereas the dental and palatal clicks are Coronal.

Earlier Traill (1986) had studied sound changes resulting in the substitution of nonclick consonants for clicks. Only unaffricated (= [+abrupt] in Traill's classification) clicks were subject to replacement by nonclicks. "Palatal" clicks were replaced either by the palatal plosive [c] ([−anterior, +distributed]) or by the dental affricates [ty ts tš] ([±anterior, +distributed]). By contrast, the replacement of the "alveolar" /!/ click "involved 'cognate' non-click velar consonants" (p. 308; see p. 304). These developments can be summarized by saying that the [+abrupt] clicks lost their [+suction] feature but preserved everything else, most especially the designated articulator. However, this plausible and attractive result presupposes that clicks parallel nonclicks in having a single designated articulator and dissents from the assumption that clicks have two designated articulators.

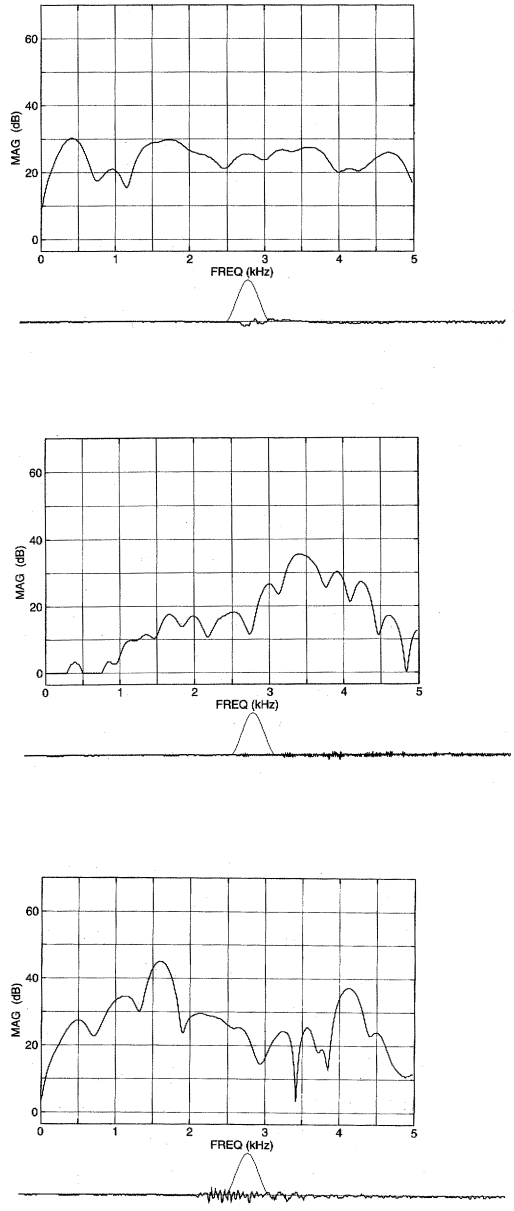


Figure 1
Spectra of English voiceless stops
From top to bottom, the spectra represent the stops in the syllables /pa/, /ta/, /ka/. Note the energy concentration in the region between 1 and 2 kHz in /ka/, and its absence in /pa/, /ta/.

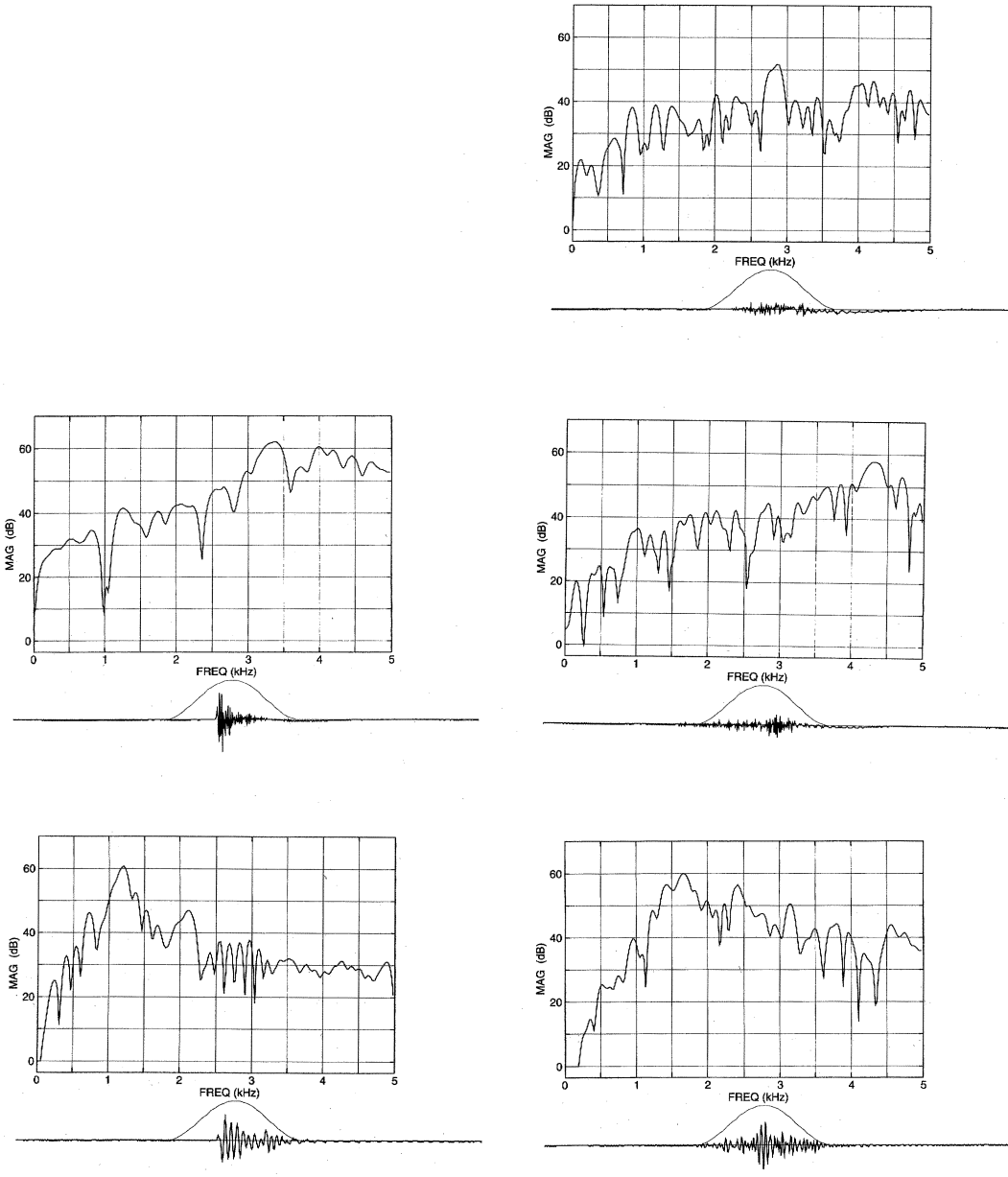


Figure 2

Spectra of !Xóõ clicks

The spectra on the left are of the [+abrupt] palatal /ǂ/ and alveolar /!/; those on the right are of the [−abrupt] bilabial /ʘ/, dental /|/, and lateral /‖/ clicks. Note the energy concentration in the region between 1 and 2 kHz in /!/ and /‖/, and its absence in /ʘ/, /ǂ/, /|/.

The fact that clicks are produced with a Dorsal (velar) closure implies that they are [+high] consonants, that is, a special kind of velarized consonant. The phonetic correlate of the feature [suction] would then be characterized as in (9), and the five types of clicks in (8) would be represented as in (10).[3]

(9) [+suction] phonemes (clicks) are [+high] consonants executed with a partial vacuum in the oral cavity. To produce the vacuum, a small cavity is created inside the vocal tract by the Dorsal articulator and one of the other two Place articulators, and the air in the cavity is removed by suction. In the case of clicks whose designated articulator is the Dorsal articulator, the second articulator involved in forming the cavity is the Coronal articulator.

(10)

	Bilabial Labial	Dental Coronal	Lateral Dorsal	Palatal Coronal	Alveolar Dorsal
Designated articulator	⊙	|	‖	ǂ	!
abrupt	−	−	−	+	+
high	+	+	+	+	+
anterior		+	+	−	−

Dental and lateral clicks, on the one hand, and palatal and alveolar clicks, on the other, have the same values for the features [anterior] and [high]. What distinguishes the two pairs is the designated articulator: for the dental and palatal clicks the designated articulator is Coronal, and for the lateral and alveolar clicks the designated articulator is Dorsal. The distinction between dental and palatal clicks and lateral and alveolar clicks thus parallels that between the Coronal stop [t] (or [c]) and the Dorsal stop [k].

2.2 Distributional Limitations on Articulator-Free Features

The distinction between [+consonantal] and [−consonantal] phonemes is at the heart of the phoneme system of every language. An important difference between these two classes of phonemes is that [−consonantal] phonemes exhibit no contrasts for any of the other AF features. There are no [±strident] glides or [±continuant] vowels. This fact is formally reflected in the restriction (11).

(11) AF features other than [consonantal] are applicable only to [+consonantal] phonemes.

As noted above, McCarthy (1988) has shown that the AF features exhibit strikingly different behaviors with regard to assimilation and other relevant phonological processes. McCarthy writes,

[3] I have not included the feature [abrupt] in (1) because the status of affricates, which it is designed to characterize, is not clear to me. (For some discussion see Steriade, in press.) With regard to the values of [anterior] I follow Sagey (1986:162). The important paper by Ladefoged and Traill (1994) contains much new information. See especially the cineradiographic profiles in their figure 2, which confirm—strikingly, to my eye—the feature analysis in (10).

> The two major class features [sonorant] and [consonantal] differ from all other features in one important respect: they arguably never spread, delink, or exhibit OCP effects independently of all other features. Expressed somewhat differently, this means that the major class features do not assimilate, reduce, or dissimilate except in conjunction with processes that affect the entire segment. Therefore the major class features should not be represented . . . as dependents of the Root node—otherwise they would be expected to spread, delink, and so on just as the other features do. Instead, the major class features should literally form the Root node, so that the Root ceases to be a class node and instead becomes a feature bundle itself. . . . All other features are now . . . in a *dependency* relation . . . with the major class features. This means that any operation on the major class features—spreading, for example—implies an operation on the features subordinate to the root. (p. 97)

This suggestion of McCarthy's is adopted here, and the features [consonantal] and [sonorant] are placed at the root of the tree (see (1)). The other four AF features—[suction], [continuant], [strident], and [lateral]—are represented as direct dependents of the root for reasons that are essentially identical with those cited by McCarthy as motivation for *not* setting up an independent Manner node in the feature tree: "Although some individual manner features do in fact assimilate, we do not ordinarily find phonological rules in languages that assimilate a set of manner features" (p. 91). This observation is also true of all four AF features under discussion here, and not only with respect to assimilation, but also with respect to other phonological processes. There is therefore no motivation for treating these four AF features as a group and for establishing a special node over them in the feature tree.[4] As already noted, this result dovetails neatly with the fact that the lowest grouping of features in the hierarchy involves features that have a given dedicated articulator. Since the four features under discussion here have no dedicated articulator, they cannot be grouped under an intermediate node in the tree.

As noted above, the feature [consonantal] must be specified for every phoneme. Since [consonantal] is an AF feature, it follows that every phoneme must have a designated articulator. The canonical representation of every phoneme will therefore include information about its designated articulator(s) in addition to a list of the features that distinguish the phoneme in question from all others of the language. This list is interpreted by the phonology in terms of the feature tree (1).

Restriction (6) limits the choice of designated articulator for [+consonantal] phonemes to the three Place articulators: Coronal, Labial, and Dorsal. No such restriction obtains for [−consonantal] phonemes. I have listed in (12) the six classes of [−consonantal] phonemes, each produced with a different designated articulator.

(12)

Larynx	[h ʔ]
Tongue Root	pharyngeals
Soft Palate	nasal glides (Sanskrit *anusvāra*)
Dorsal	vowels
Labial	[w]
Coronal	[y]

[4] In view of restriction (11) these four features figure only in [+consonantal] phonemes.

It is to be noted that in many languages [+high] vowels can occupy the syllable onset position. The distinction between such nonsyllabic vowels, whose designated articulator is Dorsal, and the Coronal and Labial glides in (12), is often overlooked in phonological and phonetic descriptions. The distinction between these two types of nonsyllabic phonemes is illustrated with particular clarity by consonant gradation in Fula. The phoneme alternations triggered by this morphologically conditioned process are illustrated in (13) (following here Sagey 1986:sec. 3.3.4; also see Anderson 1976). Like a number of other languages (e.g., Nungubuyu; Rolf Noyer, personal communication), Fula has a morphologically conditioned system of consonant gradation partly illustrated in (13).

(13)	A	r	f	s	h (= x)		w	w	y	y
	B	d	p	č	k		b	g	g	j
	C	nd	p	č	k		mb	ŋg	ŋg	nj

The aspect of this phenomenon that is of interest here is that regardless of the changes that the individual phonemes undergo, the designated articulator is preserved in all instances. This is self-evident in the first four columns. That the designated articulator is also preserved in the changes illustrated in the last four columns becomes clear as soon as it is realized that in addition to glides in which the designated articulator is Labial and Coronal, respectively, Fula also has nonsyllabic vowels in onset position, for which the designated articulator is Dorsal. The language appears to eliminate the distinction in the phonetic actualization of glides, but as shown by their different treatment in gradation, the distinction must be there in underlying representations. A further example of [−consonantal] phonemes in onset position is discussed in section 4.3.

2.3 Debuccalization

As noted by McCarthy (1988), the phenomenon of "debuccalization" by which [s] becomes [h] "is essentially the loss of the supraglottal articulation with retention only of the open glottis gesture" (p. 88). It is assumed here that formally debuccalization renders the part of the feature tree that is dominated by the Place node invisible. In view of (6), [+consonantal] phonemes must have as their designated articulator one of the three Place articulators. Since these articulators have been rendered invisible by debuccalization, it will be assumed here that the phoneme is automatically changed from [+consonantal] to [−consonantal] and its designated articulator becomes the larynx—the only articulator still visible in the feature tree.

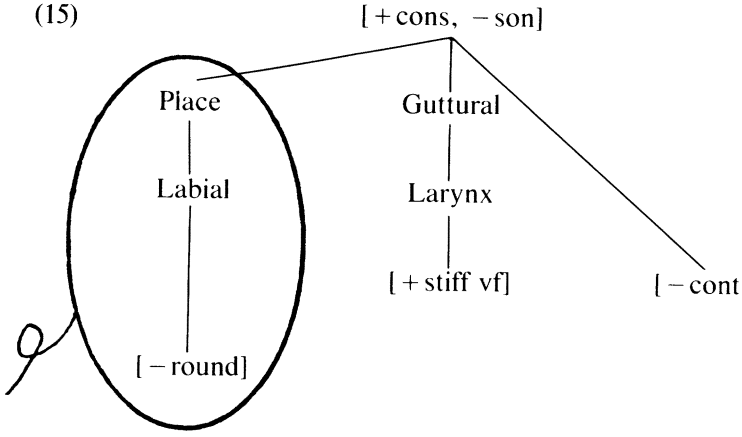
The process of debuccalization in the Kelantan dialect of Malay as discussed by Trigo (1991) is particularly instructive with regard to this phenomenon. Trigo cites the forms in (14) to illustrate the evolution of word-final consonants in Kelantan.

(14)	*Standard*	*Kelantan*	
	ʔasap	ʔasaʔ	'smoke'
	kilat	kilaʔ	'lightning'
	masaʔ	masaʔ	'cook'

balas	balah	'finish'
negatef	negatIh	'negative'
ʔalem	ʔalIŋ	'pious'
sabon	saboŋ	'soap'
dukoŋ	dukoŋ	'carry'
batal	bata:	'cancel'
ɣumah	ɣumah	'house'

According to Trigo, the change observed in the Kelantan dialect is the result of a "process of oral depletion which removes the point of articulation of word-final consonants" (p. 124). As shown in (15), debuccalization deprives an obstruent such as [p] of its designated Labial articulator and leaves the Larynx as the only accessible articulator in the representation.[5]

(15)



The tree structure resulting from debuccalization is not well formed, however, since constraint (6) requires that a [+consonantal] segment have a designated articulator that is dominated by the Place node. It will therefore be assumed that debuccalization triggers a special set of repair rules, which apply automatically at various points in the derivation and reestablish the well-formedness of the representation. In addition, in order to account for the replacement of continuants by [h] and of stops by [ʔ], it is necessary to postulate a special pair of redundancy rules. The redundancy rules are given in (16a), and the effects of the repair rules are described in (16b–c).[6]

(16) a. [−cont] → [+const gl]
[+cont] → [+spread gl]

b. Upon debuccalization a segment becomes [−consonantal] and its AF dependent features are deleted.

[5] The particular tree structure shown in (15) is motivated in section 3.
[6] For more on repair rules, see Calabrese, forthcoming, and literature cited there.

c. If the designated articulator is rendered inaccessible by the application of a rule, one of the articulators that remains accessible assumes the function of designated articulator. If no articulator remains accessible in a segment, the segment—but not its timing slot—is deleted.

It is readily seen that with the help of the rules in (16) the correct outputs are generated in all examples in (14). The redundancy rules in (16a) assign [+constricted glottis] to the stops and [+spread glottis] to the continuants. This is implemented at an early stage in the derivation and appears to hold of obstruents in many languages. The first Malay-specific rule to apply is Debuccalization. This process effectively eliminates the Place node from the feature tree and triggers the repair rules given in (16b–c). (16b) converts the segment into a glide. (16c) eliminates AF features except [−consonantal], since none of these can be stipulated in glides (cf. (11)).

(16c) also accounts for the effect of Debuccalization on nasals and liquids. When the Place node of a nasal consonant is rendered inaccessible by Debuccalization, the segment becomes a glide whose designated articulator is the Soft Palate, the only articulator that remains accessible at this point. The resulting nasal glide is attested in many languages (e.g., the *anusvāra* of Sanskrit), as was first shown by Trigo (1988).

As illustrated in (14), Debuccalization in liquids results in the loss of the entire feature complement of the affected segment. This is predicted by (16c) since liquids have no features implemented by any of the non-Place articulators. As a consequence, once Debuccalization has taken place, no articulator remains accessible in the representation, and the feature tree of the segment is deleted. Since it does not affect the timing slot of the phoneme, deletion is accompanied by lengthening of the preceding vowel.

3 The Geometry of Articulator-Bound Features

3.1 The Organization of the Place Node

Clements (1985) proposed to account for the common assimilation of place of articulation by introducing a special Place node in the feature tree that dominated the features [coronal], [anterior], [distributed], [high], [back], [round], and [labial]. The Place node has been retained in (1), but its structure has been changed because Coronal and Labial are articulators, rather than features. Coronal and Labial are therefore represented in (1) as nonterminal nodes of the tree, whereas [anterior], [distributed], [round], [back], and [high], which are features, figure as terminal nodes.

The facts of debuccalization reviewed in section 2.3 constitute a part of the motivation for not including the Tongue Root among the Place articulators and for grouping it instead with the Larynx under a common node. Additional motivation is provided by the requirement (6) that [+consonantal] phonemes have Labial, Dorsal, or Coronal as their designated articulator. Requirement (6) thus treats these three articulators as belonging to a single category, and this is formally reflected in (1) by having the Place node dominate them.

3.2 The Organization of the Non-Place Features

It was proposed in Halle 1989 that the two non-Place articulators Larynx and Tongue Root are grouped together under a common node termed here *Guttural*.[7] The grouping of these two articulators under a common node is motivated anatomically on the grounds that like the three Place articulators, they are adjacent. One might speculate that there is a single control center for the muscles in the inferior pharynx and in the Larynx that implement both glottal behavior and the positioning of the Tongue Root as well as of other structures in the lower pharynx.

Postulation of the Guttural node also provides a possible alternative solution to the problem of the "gutturals" discussed by McCarthy (1991). McCarthy shows that in many languages, most of them Semitic, the guttural phonemes—[h ʔ H ʕ X ɣ]—function as a class in a large number of phonological processes.[8] McCarthy observes that "[t]he gutturals are produced by three entirely distinct gestures: a purely glottal one in the case of the laryngeals, a retraction of the tongue root and epiglottis and advancement of the posterior wall of the laryngopharynx in the case of the pharyngeals; and a superior-posterior movement of the tongue dorsum in the case of the uvulars" (p. 7). He concludes from this that "[s]ince gutturals are produced by three entirely distinct active articulators, a natural class of gutturals is incompatible with articulator-based feature theory" (p. 10).

In Halle 1989 I proposed that the facts adduced by McCarthy can be dealt with perspicuously by assuming the feature tree (1), which includes a special (Guttural) node grouping the Larynx and Tongue Root articulators into a single constituent. The proposal is reviewed below.

Since phonetically gutturals are glide-like, I propose (17).

(17) Gutturals are [−consonantal].

Examination of the X-ray tracings as well as of other evidence adduced in McCarthy 1991, Czaykowska-Higgins 1987, Trigo 1991, and other works leads me to conclude that both the uvulars and the pharyngeals are produced with a major constriction in the lower pharynx; they differ in this respect from [h ʔ], which lack this constriction. I shall use the feature [retracted tongue root] ([RTR]) to distinguish laryngeal [h ʔ] from pharyngeal [H ʕ]. This is reflected formally in (18).

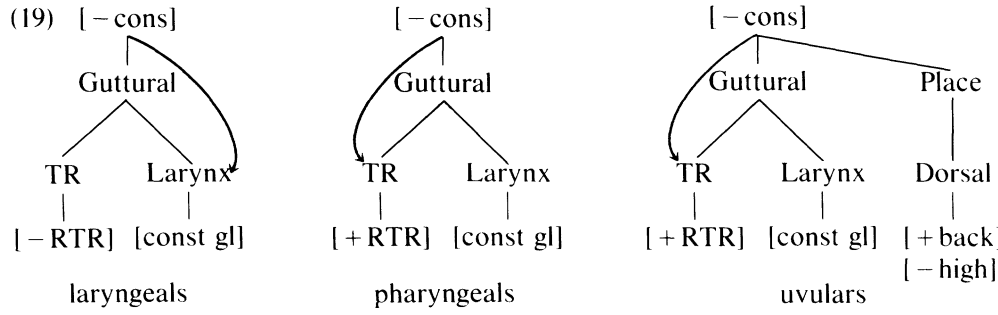
(18) Pharyngeals and uvulars are [+RTR]; [h ʔ] are [−RTR].

The three types of Semitic gutturals will be represented as illustrated in (19), where the pointer indicates the designated articulator.

[7] In Halle 1989 and 1992 the Guttural node was referred to as Laryngeal. Since the term *Laryngeal* has associations that are somewhat different from those required here, I have replaced it with *Guttural*.

[8] See Hayward and Hayward 1989 for additional evidence about the behavior of gutturals. McCarthy 1994, which supersedes McCarthy 1991, did not become available to me until after this article had gone to press.

(19)



The characterization of the gutturals can be read directly from the representations in (19): the guttural sounds are glides whose designated articulator is dominated by the Guttural node in the feature tree. It is to be noted that in (19) the uvulars are distinguished from the pharyngeals in involving the Dorsal features [+back] and [−high]. In other words, uvulars are pharyngeals with a secondary Dorsal articulation.

The gutturals are of course not the only glides in these languages; [y w] are also frequently present. As noted above, the latter glides have a designated articulator that is dominated by the Place node; they are therefore not gutturals.

Additional evidence in support of grouping the Larynx and Tongue Root articulators under a single (Guttural) node is provided by the fact that in a great many languages the Tongue Root features—both [ATR] and [RTR]—induce noticeable modifications in voice quality. Thus, in some African languages [−ATR] phonemes are pronounced with what has been described as creaky, bright, or brassy voice, whereas their [+ATR] counterparts are pronounced with breathy, hollow, or muffled voice. (See Czaykowska-Higgins 1987, Hayward and Hayward 1989, Trigo 1991, and works cited in these papers.) Moreover, as discussed most recently by Vaux (1994), there is often a correlation between [ATR] and voicing, which like voice quality is a property controlled by the Larynx, that is, by a different articulator than the Tongue Root. The existence of the Guttural node dominating these two articulators formally reflects the fact that the two articulators are more intimately linked to one another phonetically and leads us to expect such interactions.

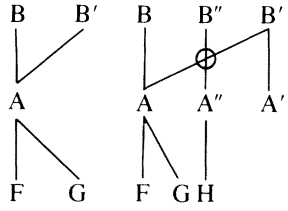
4 The Formalization of Assimilatory Processes

4.1 Introduction

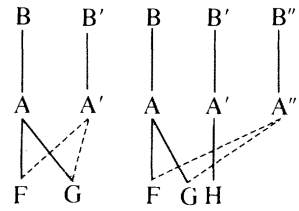
4.1.1 Clements's and Sagey's Proposals; A Counterproposal One of the central propositions of Clements's (1985) study was that only certain features assimilate together and that the different feature groups that assimilate together are defined by the nodes in the feature tree. Clements also proposed a formal implementation of this insight. In the words of Sagey (1987), he proposed that

a rule spreading two features, F and G, actually spread[s] some node A that dominates F and G, as in [(20a)]. It disallows spreading F and G individually as in [(20b). (20a) and (20b)] make different predictions in the case of long-distance rules. . . . [(20a)] predicts that any intervening segment with the node A will block spreading of F and G, even if that segment is specified only for some other feature H under A, and not for F and G. . . . [(20b)], on the other hand, predicts that only segments specified for F and G will block spreading . . . and that a segment specified only for H under A will *not* block spreading of F and G. (p. 3)[9]

(20) a.



b.



Sagey (1987) discusses the vowel copy rules of Ainu and Barra Gaelic, which are reviewed here in section 4.3, and concludes that the two languages differ with regard to the way feature groups are spread. Whereas Ainu obeys the "constituent spreading hypothesis" exemplified in (20a), Barra Gaelic "shows that the constituent spreading hypothesis is incorrect as an absolute prohibition against spreading non-constituents" (p. 7).

In Sagey's view, although Barra Gaelic "is a counterexample to the constituent spreading hypothesis in that it must spread four features separately, it is *not* a counterexample to the claim that the groups of features that may function together in phonological rules are restricted to the groups [that form constituents in the universal feature tree]. The four features spread by BVC [Barra Vowel Copy], [high, low, back, round], constitute a natural class of features. . . . They are not just a random group of features. Thus, Barra supports restricting the classes of features that rules may operate on to the constituents in [the universal feature tree], but it suggests that the constituent spreading hypothesis is the incorrect means for achieving this restriction" (p. 7). Sagey therefore proposes to treat "constituent spreading as merely inherent in the evaluation metric: rules spreading single constituents are simpler, and thus more highly-valued, than rules spreading more than one constituent" (p. 7).

In what follows I explore a different response to these counterexamples. I propose that assimilatory processes are generally notated as in (20b), that is, as spreading individual features, or terminal nodes, in the feature tree, and that nonterminal nodes in the tree are spread to adjacent timing slots only in the case of total assimilation. However, when two or more (terminal) features are spread in a given rule, they must always be exhaustively dominated by a single node in the feature tree. Thus, given the feature tree in (1), the feature set [high, back, low] may be spread in a single rule, because these

[9] The diagrams in (20) are modified versions of the diagrams in Sagey 1987.

features are dominated by the node Dorsal, whereas the set [anterior, distributed, rounded] may not be spread in a single rule, because these three features are not exhaustively dominated by a single node in the feature tree. This convention is stated more formally in (21).

(21) The linking lines that are spread from one segment to another by an assimilation rule are those of terminal nodes in the tree, with the restriction that terminal nodes spread in a given rule are all and only those dominated by a single nonterminal node.

Below I discuss several examples of assimilation processes that obey convention (21).[10]

4.1.2 On the Distinction between Marked and Contrastive Features In the discussion below occasional reference is made to *marked* and *contrastive* features and feature values. Since at this time there is no generally accepted characterization of this distinction, I briefly explain it here. Following Calabrese (forthcoming), I shall assume that the distinction between marked and contrastive features derives from the universal constraints that determine the phoneme inventory of each language. According to Calabrese, the most important of these constraints are universal marking statements of the type illustrated in (22).

(22) a. [−son, +slack vf] in env. [____, +cons]
b. [−nas, +lat] in env. [____, +cons, +son]

Each marking statement in (22) functions as a filter that excludes the cooccurrence of a particular pair of feature values. Thus, (22a) excludes voiced obstruents, and (22b) excludes liquids of the /l/ type. To admit a feature pair excluded by a given marking statement, the language must *deactivate* the statement. Thus, a language with a set of voiced obstruents must deactivate marking statement (22a), and a language with both lateral and nonlateral liquids must deactivate marking statement (22b).

The marking statements not only restrict the phoneme inventory of a language but also affect the operation of its phonological rules. In particular, as shown by Calabrese, there are phonological rules that have access only to marked feature values, that is, to feature values appearing in marking statements specifically deactivated in the language in question. For example, the Japanese rule of Rendaku, which voices word-initial obstruents in certain types of compounds, is blocked by the presence of another voiced ([+slack vocal folds]) obstruent in the word, but not by any other phoneme that is phonetically voiced, such as a nasal or a liquid. Since Japanese has voiced obstruents, the marking statement (22a) is deactivated in Japanese and [+slack vocal folds] is a

[10] McCarthy (1989:76) has objected to terminal feature spreading on the grounds that it "extracts a severe price: feature geometry is no longer a characterization of the structural relations among features; instead, it is nothing more than a notation for arbitrary subgroupings of features that exist apart from the geometry itself." The restriction on feature spreading in (21) is expressly designed to meet objections of this kind by narrowly limiting the sets of features that may be spread in a given rule.

marked feature value in this language. Rendaku is blocked only in words where this marked feature value is present. To account for this, we postulate that Rendaku is a rule for which only marked values of features are visible.

What appears to be the majority of phonological rules have access to the less circumscribed set of *contrastive* features. This set is made up of every marked feature value [αF] admitted in the language *and* its opposite [−αF]. (A small number of additional contrastive feature values are disregarded here.) A striking example of the role played by contrastive features is provided by the well-known /l/-Dissimilation rule of Latin, which converts the [+lateral] /l/ into its [−lateral] counterpart /r/ if an /l/ figures anywhere earlier in the word: for example, *nav-al-is* but *aliment-ar-is, semin-al-is* but *line-ar-is*. The rule is blocked if an /r/ intervenes between the two /l/s, as in *litor-al-is, flor-al-is*. The rule can be stated quite simply as in (23).

(23) [+lat] → [−lat] in env. [+lat] ___

This statement presupposes that each feature is represented on an autosegmental plane of its own, as is assumed in all versions of feature geometry. By assuming in addition that /l/-Dissimilation is a rule for which contrastive features are visible, we account easily both for the cases where the rule applies and for those where it fails to do so. Since Latin has both /r/ and /l/, the marking filter (22b) is deactivated in this language and both [+lateral] and [−lateral] are visible to the rule. The rule therefore applies in words such as *aliment-ar-is* and *line-ar-is,* where on the [lateral] tier nothing intervenes between the stem liquid and that of the suffix. The rule does not apply in words such as *litor-al-is,* where a [−lateral] phoneme intervenes between the stem liquid and that of the suffix.

By limiting the class of feature values that are visible to a given rule, Calabrese is able to capture most of the phenomena that in other theories were dealt with by underspecification. In view of the many difficulties encountered by underspecification (for a trenchant summary, see Mohanan 1991), I adopt Calabrese's alternative here. The great majority of rules discussed below have access to contrastive features exclusively. In view of this, I indicate the type of feature to which a rule has access only in the few cases where the features visible to the rule are not the set of contrastive features.

Full feature specification implies that the phonetically implemented feature values of a phoneme are represented at each stage in the derivation. As noted immediately above, this does not mean that all specified features are visible to every rule. Nor does it mean that the total complement of 19 features in (1) must be specified in each phoneme. There are important universal constraints that exclude the cooccurrence of certain features. One such constraint given as (11) precludes the cooccurrence of [−consonantal] with any other AF features. As a consequence of (11), the features [sonorant, suction, continuant, strident, lateral] cannot figure in [−consonantal] phonemes.

I also assume that particular features may be systematically excluded in a given language. For example, the feature [suction] is excluded in all but a small number of African languages. This fact is formally taken into account by assuming that the marking statement (24)

(24) *[+cons, +suction]

is deactivated only in these languages. Consonants in all other languages will therefore be [−suction].

A somewhat different treatment appears to be required in the case of phonemes in whose production certain articulators (and the features they execute) are excluded. As a typical example, consider the role played by the Coronal articulator in the production of Labial or Dorsal consonants in English and many other languages. It is obvious that in these languages consonants are subject to a constraint limiting to one the number of designated Place articulators that may be involved in their production. I envisage that such a constraint is included among the universal marking statements discussed above. As a consequence, the features dominated by the excluded articulators can play no role in the production of the consonants in question and do not figure in the fully specified representations of these phonemes. In other words, although all English consonants include [−suction] in their full specification, the full specification of English consonants includes only the features of the designated articulator, and none of the features executed by the other two Place articulators. The three major classes of English consonant will therefore have the feature specifications in (25).

(25)	*Labial*	*Coronal*	*Dorsal*
	[−round]	[+ant]	[+back]
		[−dist]	[−low]
			[+high]

4.2 Coronal Assimilation in Sanskrit and Tahltan

A process that sheds interesting light on the issues under discussion here is the well-known rule of Sanskrit whereby a Coronal nasal assimilates the Coronal features from a retroflex consonant that precedes it. (See Schein and Steriade 1986 for more details.) What is noteworthy about this process is that the nasal can be arbitrarily far away from the retroflex consonant that triggers the process, *provided that no Coronal consonant intervenes*. A few illustrative examples are given in (26a), and the feature composition of the major classes of Coronal consonants in Sanskrit is presented in (26b).

(26) a. kṣobh-aṇa 'quake' kṛp-aṇa 'hum'
kṣved-ana 'lament' kṛt-ana 'cut'

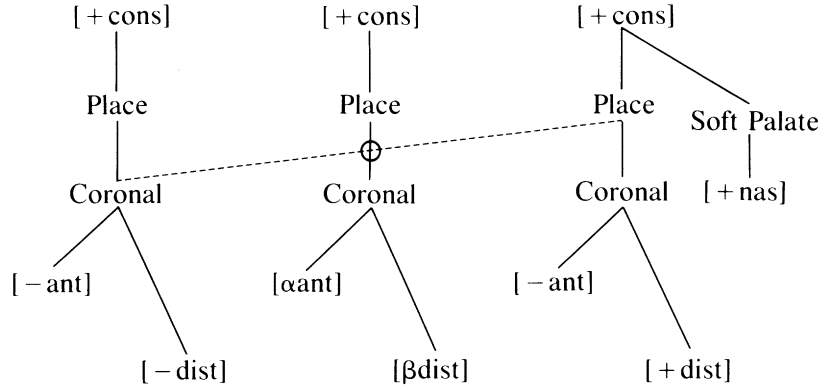
b.

	anterior	distributed
t s n	+	+
ṭ ṣ ṇ r	−	−
č š ñ	−	+

If, as suggested by some of the native phoneticians (see Allen 1953:56), Sanskrit /n/ is [+anterior, +distributed], and retroflex consonants are [−anterior, −distributed], the

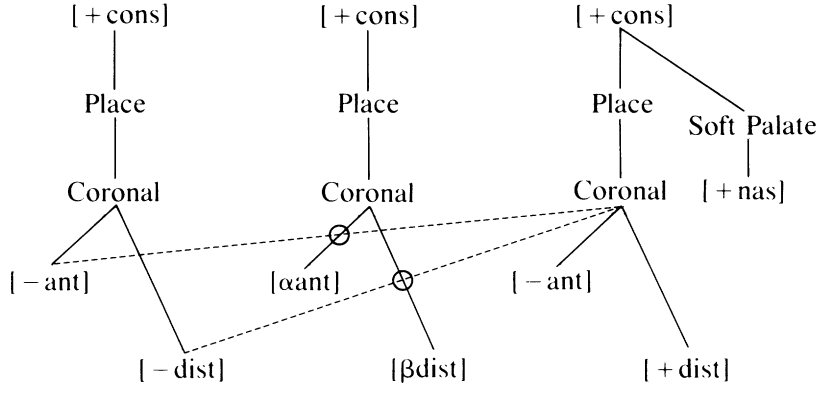
assimilation rule simultaneously spreads both features dominated by the Coronal node. In the notation now standard in the field, where nonterminal nodes of trees are allowed to spread freely, the process is formally implemented by drawing a line linking the Coronal node of the retroflex consonant to the Place node of the nasal. As shown in (27), which graphically represents the case where a Coronal intervenes between the target and the trigger of the assimilatory process, the drawing of such a line would violate the general prohibition against crossing association lines (Sagey 1988).[11]

(27)



It is readily seen that exactly the same predictions are made when the assimilation rule obeys restriction (21), except that here the Line-Crossing Constraint would be violated on the planes containing the lines associating the terminal nodes [anterior] and [distributed] with the Coronal node dominating them, as illustrated in (28).

(28)



[11] Here and below broken lines represent links that are established by the different assimilatory processes.

According to Coleman and Local (1991), the Line-Crossing Constraint is "not a constraint at all, since it does not reduce or restrict the class of well-formed Autosegmental Phonological Representations" (p. 295). Their view is based on an interpretation of feature trees that makes it possible to construe autosegmental tiers intersecting in a common line by means of a figure in a single plane. This interpretation can, however, be readily ruled out by the addition of an appropriate proviso. Once this is done, the Line-Crossing Constraint restricts autosegmental representations in the manner assumed in the literature.

The competing notational conventions differ in their characterizations of the consonant harmony process of Tahltan, an Athapaskan language spoken in British Columbia. According to Shaw (1991), Tahltan has the five series of Coronal consonants given in (29).

(29)

d	dl	dð	dz	dž
t	tL	tθ	ts	tš
t'	tL'	tθ'	ts'	tš'
	L	θ	s	š
	l	ð	z	ž
continuant	−	−	+	+	+
anterior	⟨+⟩	⟨+⟩	+	+	−
distributed	⟨−⟩	⟨−⟩	+	−	+
lateral	−	+	⟨−⟩	⟨−⟩	⟨−⟩

In (29) (and in (32) and (35)) noncontrastive feature values are enclosed in angled brackets. As shown in (29), I assume that the first two series are [−continuant] and the last three series are [+continuant].[12] In Tahltan the status of the Coronal features [anterior] and [distributed] differs in [+continuant] and [−continuant] phonemes. The features [anterior] and [distributed] are contrastive for [+continuant] Coronals, but noncontrastive for their [−continuant] counterparts. The feature [lateral] is contrastive for [−continuant] Coronals, but noncontrastive for their [+continuant] counterparts.

The assimilatory process of interest here is Coronal harmony, and for the rule implementing this process only contrastive features are visible. In Shaw's (1991) words,

> "[T]he harmony is directional, spreading from right to left. Second, the triggers and targets of the process are composed of any member of the *dð, dz* and *dž* series. Third, only the place of articulation spreads, not the manner (e.g., [−continuant] from the affricates) or the voice specification of the triggering segment. . . . [M]embers of the *d* series of coronal obstruents /d t t'/ never function to block the harmony from applying across them; nor do they function as targets of the harmony. Similarly . . . the lateral *dl* series is also fully transparent. . . . Note in particular that . . . Tahltan has (1) two separate series of transparent coronal segments, not just one, and (2) the segments that participate in the harmony cannot be analyzed in terms . . . of a single contrastive feature because *three* distinct coronal series are involved. . . . (p. 145)

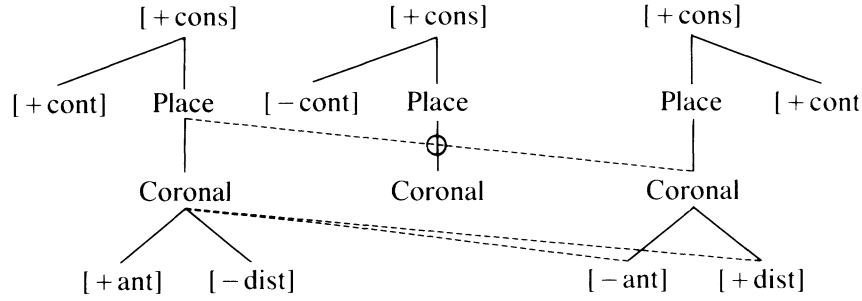
In sum, as in the Sanskrit example (26), in Tahltan both Coronal features are spread simultaneously, but unlike in Sanskrit, in Tahltan the harmony is not blocked by an intervening [−continuant] Coronal. The obvious reason for this difference is the fact

[12] Steriade (in press) has argued that the distinction between affricates and other phonemes is that the timing slot for affricates is split into two subunits and that some of the features of affricates and of affricate-like segments are linked to the first subunit, others, to the second. I venture to extend Steriade's proposal by allowing splitting for both [−continuant] and [+continuant] phonemes. Split [−continuant] phonemes are exemplified by released stops contrasting with nonsplit unreleased stops. Split [+continuant] phonemes are affricates, contrasting with ordinary continuants whose timing slot is not split.

noted above that, unlike in Sanskrit, in Tahltan the assimilating Coronal features are not contrastive for [−continuant] Coronals and hence are invisible, since only contrastive features are visible to the rule of Coronal harmony.

In (30) the single broken line connecting Coronal to Place shows the process in the standard notation, whereas the two broken lines lower in the diagram connecting the [anterior] and [distributed] nodes with the Coronal node of the first segment portray the process in conformity with (21).

(30)



It is obvious that the simultaneous spreading of the Coronal features [−anterior] and [+distributed] from the last to the first phoneme in (30) does not violate the Line-Crossing Constraint, since, as noted, in the intervening stop these features are noncontrastive and hence invisible to the rule. By contrast, if the process is formalized as spreading the nonterminal Coronal node, any intervening Coronal consonant results in a violation of the Line-Crossing Constraint. Since the facts conform to the former rather than to the latter formalization, the Tahltan harmony process constitutes evidence in favor of the notational convention (21).

In the theoretical framework employed by Shaw, Tahltan harmony is treated by postulating that in the representation of consonants of the first two series in (29) the Coronal node is unspecified. This move makes it impossible for consonants of this type to satisfy condition (6); it is also subject to the problems generally inherent in underspecification noted by Mohanan (1991). These problems do not arise if the notational convention (21) is adopted.

4.3 Vowel Copy Rules

The formalism for assimilatory processes proposed in (21) accounts directly for the common phenomenon where all features of a vowel are spread to a preceding or following vowel without regard for the nature of the intervening consonant(s). The reason for the freedom with which one vowel copies features from another across intervening consonants is that the assimilated vowel features are primarily features executed by the Labial or Dorsal articulators, and that among consonants Labial and Dorsal features are generally noncontrastive and hence not visible to the most common phonological rules, which have access only to contrastive features. In view of this, we expect Dorsal and Labial

features in vowels to spread freely across consonants, but we do not expect the same features to spread freely from one consonant to the next across an intervening vowel.

4.3.1 Vowel Copy in Ainu An example relevant to this issue is the vowel copy rule of Ainu discussed by Itô (1984) and Sagey (1987). In Ainu several morphemes are spelled out as vowel suffixes whose quality is identical with that of the stem vowel. Among such morphemes are the "possessed" suffix of nouns and the transitivizing suffix of verbs. Following Itô, I limit the discussion to the transitivizing verb suffix, of which examples are given in (31).

(31) a.

mak-a	'open'	tas-a	'cross'		
ker-e	'touch'	per-e	'tear'		
pis-i	'ask'	nik-i	'fold'		
pop-o	'boil'	tom-o	'concentrate'		
tus-u	'shake'	yup-u	'tighten'		

b.

ray-e	'kill'
hew-e	'slant'
čiw-e	'sting'
poy-e	'mix'
tuy-e	'cut'

Maddieson (1984) gives for Ainu the rather impoverished system of phonemes illustrated in (32).

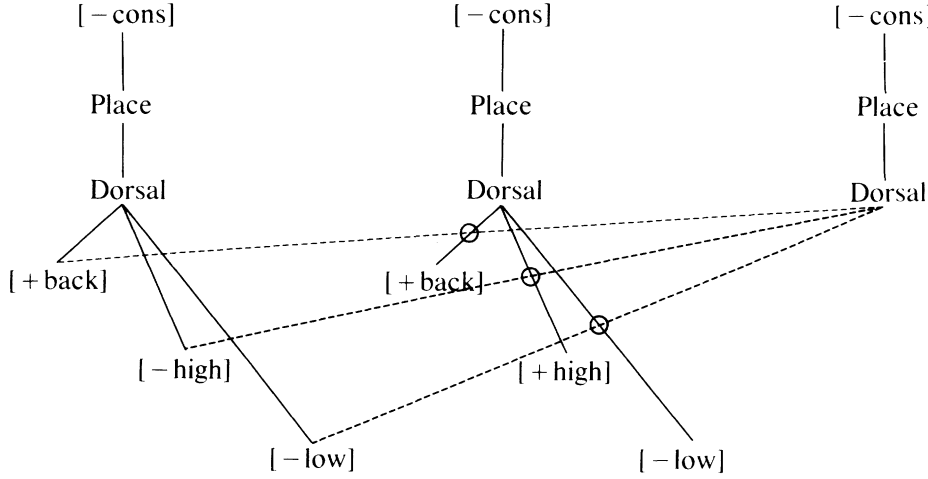
(32)

p	t	č	k	h						
	s									
m	n									
	rr									
		i		u		e		o		a
high		+		+		−		−		⟨−⟩
low		⟨−⟩		⟨−⟩		−		−		+
back		−		+		−		+		⟨+⟩

Of importance for matters under discussion here is that the Ainu glides [y w] are positional variants of the high vowels [i u]. As can be seen in (32), with the exception of [±anterior] none of the features dominated by any Place articulator is contrastive for the consonants. Hence, given convention (21), it is to be expected that the Dorsal features that define the vowels in Ainu will spread freely across intervening consonants, for the spreading will not violate the Line-Crossing Constraint. And this is in fact the case, as illustrated in (31a). By contrast, it is to be expected that the vowel features will not spread across a [y w] glide, since in Ainu these glides are actually high vowels and therefore possess a full complement of Dorsal features that will prevent the spreading of the vowel features. As shown by the examples in (31b), there is indeed no vowel copy across glides; instead, the suffix vowel is implemented uniformly by [e], the "default" vowel of Ainu. This is illustrated in (33).[13]

[13] An anonymous *LI* reviewer has observed that since [low] is noncontrastive in the glides, the assimilation of this feature will not be blocked by an intervening glide. There are various simple ways of ruling out this consequence, for example, by invoking repair rules. Working out a precise proposal would, however, involve investigation of details of Ainu phonology that would take us far beyond the limits of the present study.

(33)



Itô notes that Vowel Copy is not the only rule involved in the spelling out of the suffix vowel. Certain Ainu verb stems take suffix vowels that are [+high], and these are not subject to Vowel Copy. If the stem vowel is [−low], only [i] is used. If the stem vowel is the [+low] [a], the choice of the suffix vowel is an idiosyncratic property of the stem: some stems choose [i], others [u]. Instead of Vowel Copy, the [+high] suffixes are subject to a rule that Itô calls Melodic Dissimilation. This rule, which according to Itô also applies stem-internally in diphthongal stems, changes [αback] to [−αback] in the succeeding vowel if the stem vowel is [αback]. Like Vowel Copy, this rule is sensitive only to features that are contrastive. Since, as shown in (32), [back] is not contrastive in [a], the stem vowel [a] cannot trigger Melodic Dissimilation and the idiosyncratically assigned [back] feature is preserved.[14]

4.3.2 Vowel Copy in Barra Gaelic Sagey (1987) compares the Ainu Vowel Copy process with the very similar process in the Barra dialect of Gaelic. According to Clements (1986), Sagey's main source, Barra has the consonant system in (34) and the vowel system in (35).

(34)

Labial	p	b	f	v	m											
Coronal	t	d	s		n	r		t'	d'	s'			r'	l'		
					N	R	L					N'		L'		
Dorsal	k	g	x	γ				k'	g'	x'	γ'					

[14] It is to be noted that the dissimilatory property of the Melodic Dissimilation rule informally stated above cannot be expressed formally as a node-spreading process; rather, it requires the use of variables as feature coefficients. It should also be remarked that since this rule must be feature-changing, there is little advantage to be derived from following Itô's procedure of underspecifying the suffix vowel in the cases where Vowel Copy is involved and making Vowel Copy a feature-filling rule.

(35)

	i	ɨ	u	e	ʌ	o	æ	a	ɔ
high	+	+	+	−	−	−	⟨−⟩	⟨−⟩	⟨−⟩
low	−	−	−	−	−	−	+	+	+
back	−	+	⟨+⟩	−	+	⟨+⟩	−	+	⟨+⟩
round	⟨−⟩	−	+	⟨−⟩	−	+	⟨−⟩	−	+

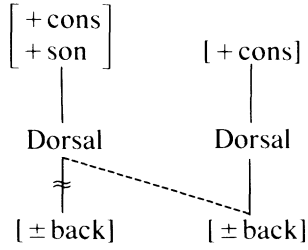
The most interesting aspect of the Barra consonant system for matters under discussion here is the existence of two parallel sets of consonants: [±back].[15] The Labials systematically lack this contrast, but the Dorsals and Coronals have almost complete pairs, the only exception being the absence of [−back] /n'/ and /R'/ and of [+back] /l/. Following Sagey (1987), I interpret Clements's [ʃ] as [−back] /s'/ and his [c j] as [−back] /x' γ'/. [n r l] represent nonlenited Coronal sonorants; [N R L] are their lenited counterparts.

The Barra vowel system consists of the nine vowels shown in (35). The inventory is reduced in unstressed syllables, with schwa replacing all mid vowels.

In Barra vowels are inserted to break up certain consonant sequences. Clements shows that the sequences so affected consist of a sonorant followed by a consonant, subject to a number of further constraints. The most important of these is the requirement that the consecutive consonants not be homorganic; that is, they must have distinct designated articulators.

As shown in (34), Dorsal and Coronal consonants contrast with regard to the feature [back], but for Labial consonants [back] is never contrastive. Barra sonorant consonants assimilate backness from an immediately following consonant. Since only contrastive features are visible to the assimilation rule, this feature-changing rule involves both Dorsals and Coronals, but not Labials, since, as just noted, backness is not contrastive for Labials. The backness assimilation rule is given by Clements in the form (36).

(36)



As shown in (37), the rule of Epenthesis breaks up sonorant-consonant sequences by inserting a copy of the preceding vowel between the sonorant and the consonant. It is important to note that the constraint against insertion into linked structures does not hold for sequences that have undergone Backness Assimilation by rule (36). Thus, underlying

[15] The apostrophe after a consonant denotes that the consonant is [−back]. The absence of the apostrophe denotes that the consonant is not [−back]; that is, it is either [+back] or not marked for [back].

/merk'/ 'rust' undergoes Backness Assimilation before Epenthesis breaks up the sonorant-consonant cluster.

(37)	u	urpel	→	urupel	'tail'
	ɨ	ɨn(ɣ)əs	→	ɨnɨ.əs	'Angus'
	i	t'imx'al	→	t'imix'aL	'round about'
	e	mer'k'	→	mer'ek'	'rust'
	ɔ	ɔrm	→	ɔrɔm	'on me'
	æ	æms'ir'	→	æmæs'ir'	'time'
	a	marv	→	marav	'dead'

In the Barra vowel system there is a systematic [±round] contrast among the back vowels. Since all vowel features are copied, the Barra Vowel Copy (BVC) rule must involve not only the features dominated by the Dorsal articulator, but also the features dominated by the Labial articulator. This means that BVC involves, not the features of the Dorsal node, but those of the Place node above it (cf. (1)).

As shown in (38), the copy is not complete in every case.

(38)	mʌr'ev	'the dead'	bul'ik'	'bellows' (gen.sg.)
	færak	'anger'	dɨr'i	'fishing line' (gen.sg.)

As Clements (1986) notes, the copied vowel here differs from its source in the feature [back], and the value of this feature is predictable from that of the preceding sonorant: when the sonorant is [−back], so is the following vowel; and when the sonorant is [+back], so is the epenthetic vowel. Formally this would be implemented by a rule spreading [back] from a sonorant to the vowel on its right. As shown by the examples *t'imix'aL* 'round about' and *æmæs'ir'* 'time' in (37), Labial sonorants constitute an exception to this in that they allow the feature [−back] to be assimilated across them, even though the Labials are phonetically—but not contrastively—[+back].

In discussing these examples, Sagey (1987) writes,

> The results of BVC . . . show that it must spread the features [high, back, low, round] individually. . . . Across a consonant specified for [back], [high, low, round] will spread from the vowel, [back] will spread from the consonant [see (37)]. Across a consonant unspecified for [back], all four features will spread from the preceding vowel. (p. 6)

This behavior is to be expected given the convention (21) for notating assimilatory processes. BVC copies all features dominated by the Place node onto the epenthetic vowel from the directly preceding vowel. If a Labial consonant intervenes between the two vowels, all features are copied, because for Labial consonants in Barra Gaelic no Place feature is contrastive. If the intervening sonorant consonant is Coronal—that is, a consonant for which the Place feature [back] is contrastive—[back] cannot be copied from the preceding vowel, because linking this feature to the epenthetic vowel would violate the Line-Crossing Constraint. The peculiar exceptions to BVC thus follow directly

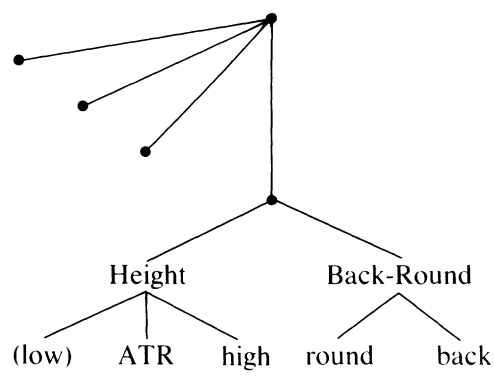
if the notational convention (21) is adopted. They therefore constitute good evidence in support of the convention.[16]

5 Alternatives to Feature Tree (1)

5.1 Odden's (1991) Alternative to the Feature Tree (1)

Odden (1991) proposes the feature tree shown in (39).

(39)



The feature organization in (39) differs from that in (1) in that (a) it includes the node Vowel Place and (b) it groups the features [round] and [back] under one node and the remaining common vowel features—[low, ATR, high]—under another node. Odden disagrees specifically with the assumption central both to Sagey's (1986) study and to the feature organization adopted in (1) that features executed by a given articulator are to be grouped together. He notes that his feature tree "departs most radically from previous models in not placing [round] under the Labial node" (p. 266). He correctly identifies the objection to this model as being motivated by the consideration that "each articulator has a corresponding node which dominates all and only the features executed by that articulator" (p. 266) and remarks that "[o]n these grounds, tongue position features could

[16] This analysis has been challenged by Ní Chiosáin (1994). (I am indebted to Dr. Ní Chiosáin for providing me with a preprint of her paper.) According to Ní Chiosáin, Barra Vowel Copy involves "the spreading of height features only in the case of non-low vowels. . . . In the case of low vowels, on the other hand, it appears that non-constituent spreading of Height and [round] may occur" (p. 12). She thus separates Vowel Copy of the low vowels from that of the nonlow vowels and denies that in the latter case there is copying of the feature [back].

Central to Ní Chiosáin's argument is the proposition that "the [back] specification of (all) short vowels and the [round] specification of non-low short vowels in Barra Gaelic are independently determined by adjacent consonants. . . . Therefore the lexical vowel inventory of Barra Gaelic is greatly simplified, involving a height distinction (three heights) and a (possible) rounding contrast in the low vowel only" (p. 6). The language, however, exhibits a three-way contrast for short high vowels in word-initial position, as shown by forms such as *ini.es* 'Angus', *iNeN* 'same', *us'ak* 'a lark', cited by Ní Chiosáin. To account for this contrast, Ní Chiosáin posits an initial "empty" consonant specified only for the features [back] and [round]. In other words, the contrasts phonetically present in word-initial vowels are underlyingly represented on a phonetically unactualized (i.e., abstract) consonant, whose sole raison d'être is to account for the vowel contrasts that were removed in underlying representations in order to simplify "the lexical vowel inventory of Barra Gaelic." This is a dubious move, and since it is crucial to Ní Chiosáin's alternative, it makes it difficult to view her alternative as an improvement.

not be a constituent with a lip protrusion feature, since lip protrusion and tongue backing are not executed by the same articulator" (p. 266). Although Odden has "no quarrel with the belief that aspects of phonological structure should be grounded in phonetic properties," he feels that "decisions about feature geometry are not to be based on *a priori* decisions about vocal tract anatomy, but should be grounded on generalizations regarding phonological processes, as well as acoustic and articulatory arguments" (p. 267), and he qualifies as a priori the "decision to place [round] under Labial" (p. 267).[17]

Although Odden's characterizing the decision to place [round] under Labial as a priori is unjustified, his case against the feature organization in a tree like (1) rests only marginally on this proposition. The heart of Odden's case is a series of examples of assimilatory phenomena purporting to involve groups of features that are "unnatural" in terms of the feature tree (1). In particular, he presents several examples where the features [back] and [round] assimilate together to the exclusion of other vowel features and other examples where [ATR] and [high] assimilate together. Since both feature pairs involve distinct articulators and since other features executed by these articulators are not also assimilated in these processes, Odden's examples constitute prima facie evidence against the feature groupings in (1), which, as noted, are based on the assumption that features executed by a given articulator are grouped together.

In the following sections I examine these examples and propose reanalyses in order to show that the facts can be accounted for equally well by means of the feature groupings in (1) and do not therefore require us to replace these natural groupings with Odden's alternative (39).

5.1.1 Joint Assimilations of [back] and [round] According to Odden (1991), the harmony rule of the Wikchamni dialect of Yokuts is an example of an assimilatory process that propagates [back] and [round] but not also [high]; the process thus spreads a Dorsal feature together with a Labial feature while failing to spread a second Dorsal feature that is contrastive in Wikchamni. This behavior is not compatible with the feature organization in (1) and thus would seem to support Odden's alternative (39).

The Wikchamni dialect has the five-vowel system in (40).

(40)

	i	ɨ	u	o	a
high	+	+	+	−	−
low	−	−	−	−	+
back	−	+	+	+	+
round	−	−	+	+	−

[17] In a footnote Odden raises questions about one of the basic facts of articulatory phonetics:

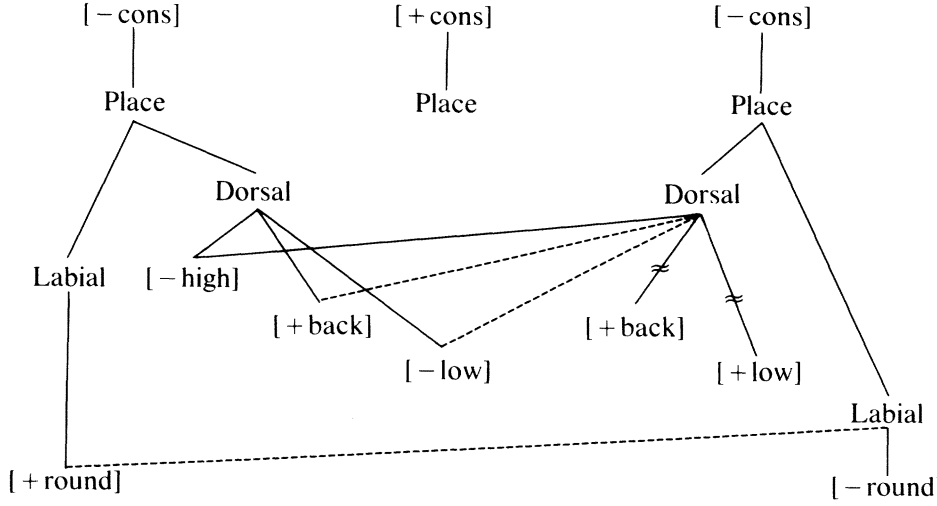
> It is far from clear, from the perspective of phonetic theory, what an "articulator" is in any meaningful way, how one distinguishes one articulator from another, or whether phoneticians and phonologists are speaking of the same thing when speaking of "articulators." In short, it is far from certain that the notion of "articulator" as used by phonologists corresponds in any useful way to a real construct in phonetic theory. (pp. 286–287)

Odden cites no evidence in support of the claims implicit in this passage in spite of their far-reaching implications both for the discipline of phonetics and for phonology. For some discussion of articulators, see section 1 above.

According to Odden, Wikchamni harmony spreads the features [back] and [round] from a given vowel rightward to vowels in consecutive syllables provided that they agree in the value of the feature [high]. This statement is not altogether accurate. If Odden's feature composition given in (40) is correct, the feature [low] also participates in the harmony, as shown by his example /t'oyxat/ → /t'oyxot/ (p. 278). Thus, the correct characterization of Wikchamni harmony is that it spreads the features [back, round, low] from a given vowel to the vowels on its right provided that they agree in the value for the feature [high]. As in Odden's analysis, the restriction on the harmony domain is implemented here by fusing the [high] feature in vowels of consecutive syllables, so that sequences with consecutive vowels that agree in their specification for [high] are represented with a single branching [high] node; see (41).[18]

Wikchamni harmony can then be treated as a harmony rule, which, in conformity with (21) and given the vowel system (40), spreads the features of the Place node—[back, low, high, round]—iteratively from left to right over a subsequence containing vowels linked to a single branching [high] node. Since being linked to the same [high] node as the vowel triggering the harmony is a precondition for a vowel to undergo the harmony process, the spreading of [high] is vacuous. (41) illustrates the assimilation process in the case of an /o-a/ sequence being converted to /o-o/.

(41)



The alternative proposed here treats Wikchamni harmony as an instance of total vowel harmony that fails to affect the feature [high] because of the effects of a previous rule. As noted above, it automatically provides the correct treatment for the feature [low], which on Odden's account would have to be subject to an extra rule. The Wikchamni

[18] This treatment was first suggested by Cole and Trigo (1988). See also Archangeli 1985 and Cole 1991 for valuable additional discussion of issues surrounding this question.

facts thus do not argue for the existence of a Back-Round node in the feature tree, as proposed by Odden. The phonetically more natural tree (1) provides a superior account of the facts.

As another example of the simultaneous spreading of [round] and [back] Odden discusses the suffix harmony of Eastern Cheremis (Mari). This harmony process is restricted to the mid vowel /ə ~ e/ in absolute word-final position. The language has the vowel system in (42).

(42)

	i	ü	u	e	ö	o	a	ə
high	+	+	+	−	−	−	−	−
back	−	−	+	−	−	+	+	+
low	−	−	−	−	−	−	+	−
round	−	+	+	−	+	+	−	−

In absolute word-final position schwa surfaces as /o/ if the nearest preceding full vowel is /u o/, as /ö/ if the preceding full vowel is /ü ö/, and as /e/ elsewhere. Odden analyzes this as an instance of a harmony process in which [back] and [round] are spread simultaneously. However, the simultaneous spreading of the two features fails to account for the appearance of /e/ after unrounded back vowels such as /a/ or /ə/, as for example in the forms *šužar-že* 'his sister' and *əštə-me* 'made' cited by Odden.

To account for the entire set of forms, I propose that in absolute word-final position schwa becomes /e/, that is, [−back]. In Eastern Cheremis all full vowels are accented, whereas schwas are unaccented. (For details see Halle and Vergnaud 1987:70.) The harmony process therefore consists of spreading the features of the vowel bearing the word stress to the word-final vowel. The process itself is composed of two distinct spreading rules. The first rule spreads the feature [round] from the accented vowel to the /e/ in absolute word-final position. Final vowels sharing the feature [+round] with the accented vowel as a result of the application of this rule are subject to a second harmony rule that, in a fashion similar to that encountered in Wikchamni, spreads the feature [back].[19]

On this account, then, the Eastern Cheremis harmony provides no evidence for the geometry of the feature tree since the harmony involves two separate rules each spreading a single feature.

A third example adduced by Odden as showing the joint assimilation of [back] and [round] is a vowel assimilation process in Tunica. This language has the seven-vowel system in (43).

[19] Some morphemes with word-final /e/ do not undergo harmony. According to Odden, the existence of such word-final /e/ renders a two-rule analysis of the sort proposed here untenable, because "there is no reason for [a] morpheme to be an exception to both rules." This criticism does not apply to the particular analysis proposed here: since the [back] harmony rule can apply only to forms that have undergone [round] harmony, morphemes that are exceptions to [round] harmony are automatically also exceptions to [back] harmony.

The analysis of the harmony process by means of two distinct rules follows such earlier works as Gruzov 1960 and Ivanov and Tuzharov 1970.

(43)

	i	u	e	o	æ	ɔ	a
high	+	+	−	−	−	−	−
back	−	+	−	+	−	+	+
low	−	−	−	−	+	+	+
round	−	+	−	+	−	+	−

According to Odden,

> [the] low vowel *a* becomes *æ* after a front non-round vowel, and becomes *ɔ* after a back round vowel. . . . Besides the Back-Round harmony rule, there are two additional processes which are relevant to the discussion. By the first rule, Truncation, the leftmost of two adjacent vowels deletes. The relevant vowel cluster may be brought into existence by applying a rule to delete intervocalic *h* which is preceded by at least two syllables. . . . By a second process of Preglottal Apocope, an unstressed vowel deletes before glottal stop. . . . This [harmony] process also applies across *ʔ* and, at least in the negative affix *ʔaha*, across *h*. . . (pp. 274–275)

In discussing how this harmony process might be formalized, Odden writes,

> The feature [round] is contrastive for the two low back vowels *ɔ* and *a*. Therefore, the simultaneous assimilation of [back] and [round] seen above cannot be reduced to assimilation of [back] plus default assignment of [+round] to back (low) vowels, since the back vowel *a* itself is [−round]. As these data also show, vowel height is not assimilated by this process, so the rule cannot be construed as spreading of the Place node. Only [back] and [round] are assimilated . . . (p. 276)

Odden sees in these facts further vindication of his proposal that the feature tree must contain a node exclusively dominating the features [back] and [round].

As pointed out to me by an *LI* reviewer, our main source on Tunica, Haas (1940), states explicitly that in addition to the low vowel /a/ the harmony affects the two mid vowels /e/ and /o/ (see Haas's statement and examples in her sec. 2.221) and, more important still, that the rounded low vowel /ɔ/ is exempt from harmony (as are the high vowels /i u/) and that data for all other vowel sequences are lacking (p. 22, n. 1). The Tunica harmony process must therefore be reformulated so as to include as targets the mid vowels /e o/ as well as the low vowel /a/, yet exclude the low vowel /ɔ/ and possibly also /æ/.

At the very least it will be necessary to restrict the target of the assimilation process to [−high] vowels, and further conditions will have to be stated with respect to [+low] vowels. Thus, both features [high] and [low] will have to be mentioned as conditions on the target. I note that in the Wikchamni example (41) the feature [high] that was a precondition for the application of harmony was exempt from the harmony process and that a similar constraint was operative in Eastern Cheremis. I conjecture that this is a reflex of the following more general constraint on assimilatory processes:

(44) Features that are a precondition for the application of an assimilation rule to a target phoneme are passed over in applying the rule.

In the light of (44), the Tunica assimilation process can now be stated as spreading all Place features. Since the target of the process must be [−high, −low], on the one hand, and the unmarked [+low] vowel, on the other, the features [high] and [low] are preconditions for the assimilation process and hence will be passed over in applying the rule.

In sum, the Tunica harmony rule can be formulated to spread all Place features of one vowel to the next, subject to the special condition affecting the features [high] and [low]. In view of constraint (44), the rule will in effect spread only the features [back] and [round]. The facts of Tunica, like those of Wikchamni and Eastern Cheremis, can thus be accounted for without postulating a node in the feature tree that exhaustively dominates the features [back] and [round].

Before leaving Tunica, I note that Tunica harmony is restricted to vowel sequences with or without intervening glides, but without intervening consonants. The fact that the harmony is not blocked by intervening glides suggests that the harmony rule applies to a string of consecutive [−consonantal] phonemes. That is, harmony in Tunica, like that in Wikchamni, is subject to a requirement that the elements in the string share a feature: [αhigh] in Wikchamni, [−consonantal] in Tunica. Since [consonantal] is represented on the root of the feature tree, whereas [high] is a terminal node of the tree, it is not obvious that feature sharing should, or can, be represented in the same way in the two cases. As this is a problem of some complexity that is of peripheral importance to the main issue under discussion here, I leave its resolution to future research.

Odden observes that a feature organization like that in (1) would experience difficulty in characterizing the Vowel Copy rule of Klamath: "Since multiple vowel place features are spread, this process would have to be expressed as spreading the Dorsal node from the root vowel to the target vowel. . . . But such spreading would be impossible, since there is an association line between the Place and Dorsal nodes of the intervening dorsal consonants which stands between target and trigger . . ." (p. 264). This argument holds against a framework in which the assimilation process *must* be characterized by means of spreading nonterminal nodes in the feature tree. In a framework in which by virtue of condition (21) the process is formally expressed by spreading terminal nodes in the feature tree, the problem does not arise. Thus, pace Odden, the Klamath data can be readily handled with the anatomically motivated feature organization in (1).

The Klamath case merits attention also because the language has a systematic contrast between velar and uvular stops, represented below respectively by /k/ and /q/. The Dorsal consonants of Klamath exhibit a contrast between a [+high] and a [−high] series. Specifically, the stops of the velar /k/ series are [+high] and those of the uvular /q/ series are [−high].

Klamath has a Vowel Copy rule that spreads the features of the stem vowel onto the vowel of certain prefixes. Assuming that contrastive features are visible to Klamath Vowel Copy, the rule will not be able to spread the feature [high] across velars and uvulars, since this would violate the Line-Crossing Constraint. As shown below, how-

ever, there is no reason to assume that this blocks Vowel Copy from distinguishing all the vowels of the language. Klamath has a four-vowel system, represented in the main source of data for this discussion, Barker 1964, as /i e o a/. Since Barker describes both /e/ and /a/ as low (see, e.g., pp. 22, 31, 34), I assume that the Klamath vowels have the (contrastive) feature complexes shown in (45).

(45)

	i	e	o	a
back	−	−	+	+
low	−	+	−	+

Vowel Copy can now be formalized as spreading all Dorsal features of the stem vowel onto the vowel of the prefix. Since [high] is not contrastive for Klamath vowels, the blocking of the spreading of [high] by intervening velars and uvulars does not eliminate any vowel contrasts. The missing [high] feature—as well as [round]—is supplied by the appropriate repair rules (see footnote 6).

5.1.2 Joint Assimilation of [ATR] and [high] Odden (1991) adduces a separate set of facts to illustrate the joint assimilation of the features [ATR] and [high]. Given Odden's assumptions, these facts justify the existence in the feature tree of a common node exhaustively dominating the features [ATR] and [high]. Since these features are executed by different articulators, the fact that the two features need to be directly dominated by a common node constitutes evidence against the feature organization (1). If (1) is to be maintained, it is therefore necessary to reanalyze the data adduced by Odden.

In Kimatuumbi "stem-medial vowels are either (phonetically invariant) *a*, or are selected from the [+high, +ATR] vowels *i* and *u*. The stem-medial non-low vowels assimilate the value of [high] and [ATR] from the preceding non-low vowel. This height harmony rule is observed systematically throughout the lexicon . . ." (p. 281). Odden notes an important exception to this rule: "[T]he vowel *ɛ* does not cause *u* to assimilate, although all other vowels cause *u* to assimilate, and *ɛ* will cause *i* to assimilate" (p. 282). Moreover, "various suffixes such as the perfective (*-itɛ*) fail to harmonise, and stems such as *lɔɔkiy*, which are lexical exceptions to Height Harmony are exceptions to assimilations of both features" (p. 282). As Odden correctly observes, this exceptional behavior, "however it is to be stated, should not be stated twice" (p. 282). Odden believes that this necessitates characterizing the harmony as a single process spreading both the features [high] and [ATR] simultaneously.

Odden's argument does not seem compelling. As shown in the analysis sketched below, it is possible to postulate that there are two distinct harmonies, one spreading the feature [high] and the other spreading the feature [ATR]. Since the second process is triggered by features supplied by the first, exceptions to the first process automatically fail to undergo the second process. But if [high] harmony is distinct from [ATR] harmony, the Kimatuumbi data provide no evidence for the Height node in Odden's tree (39).

The vowel phonemes of Kimatuumbi are given in (46).

(46)

	i	u	ɪ	ʊ	ɛ	ɔ	a
high	+	+	+	+	−	−	−
ATR	+	+	−	−	−	−	−
low	−	−	−	−	−	−	+
back	−	−	+	+	−	+	+

The facts to be accounted for are illustrated in the table (47), from Clements 1991, in which the transcription is modified to conform to that of (46).

(47)

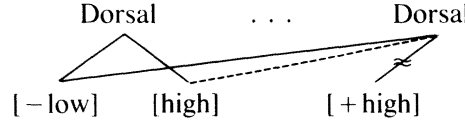
Underlying	*Surface*	*Example*	
i+i	i+i	yipilya	'thatch with for'
i+u	i+u	libulwa	'be ground'
ʊ+i	u+i	utitika	'be pullable'
u+u	u+u	yupulwa	'be served'
ɪ+i	ɪ+ɪ	twɪkɪlwa	'be lifted' (like load)
ɪ+u	ɪ+ʊ	tɪkʊlya	'break with'
ʊ+i	ʊ+ɪ	ʊgɪlwa	'be bathed'
ʊ+u	ʊ+ʊ	kʊmbʊlya	'beat with'
ɛ+i	ɛ+ɛ	chɛɛngɛya	'make build'
ɛ+u	ɛ+u	kwɛmulya	'comb' !
ɔ+i	ɔ+ɔ	bɔɔlɛlwa	'be de-barked'
ɔ+u	ɔ+ɔ	bɔmɔlwa	'be destroyed'
a+i	a+i	asimilwa	'be borrowed' !
a+u	a+u	tyamulya	'sneeze on' !

I have marked with an exclamation point (!) examples where assimilation does not take place.

As shown in (47), harmony proceeds from left to right and the vowels undergoing harmony are [+high, +ATR]. The effect of the harmony is for the high vowel on the right to assimilate the value of the feature [high] from a preceding [−low] vowel. That the harmony affects only [+high, +ATR] vowels is shown by the fact that wherever harmony fails to take place (i.e., in the examples marked with the exclamation point), the vowel on the right is [+high, +ATR].

This part of the harmony process will be implemented formally with two rules. The first merges the feature [−low] of two adjacent vowels. The second spreads [high] from left to right over a sequence of vowels sharing the feature [−low]. The effects of applying these rules are illustrated in (48), where the solid line reflects the result of [−low] merger and the broken line, that of [high] spread.

(48)



The spreading of [high] will not occur in sequences such as [ɛ + u] that are exceptions to [−low] spread, or in the lexical exceptions to this rule such as *lɔɔkiy* mentioned by Odden.

A third rule spreads [ATR] from left to right over sequences of consecutive vowels that share [−high]. This rule therefore applies only to sequences that have undergone the first harmony process. Sequences to which the first two rules fail to apply—for any reason—are ineligible for [ATR] harmony.

Since this analysis does not require the simultaneous spreading of [ATR] and [high], the Kimatuumbi facts cannot be viewed as evidence supporting Odden's proposal that these two features must be dominated by a common node in the feature tree.

The Kinande facts in (49), briefly discussed by Odden, provide yet another illustration of a situation where [high] harmony must be implemented by a rule different from the one that implements [ATR] harmony.

(49)

eri-lim-ir-a	'to exterminate for'
eri-huk-ir-a	'to cook for'
ɛrɪ-lɪm-ɪr-a	'to cultivate for'
ɛrɪ-hʊm-ɪr-a	'to beat for'
ɛrɪ-hɛk-ɛr-a	'to carry for'
ɛrɪ-bɔh-ɛr-a	'to tie for'
ɛrɪ-kar-ɪr-a	'to tie for'
eri-himat-ɪr-a	'to squeeze for'
eri-gumat-ɪr-a	'to stuff in mouth for'

The phenomenon of interest is the effect that the stem vowel has on the applicative suffix /ir/ on its right. It is obvious that the suffix always assimilates [ATR] from the stem vowel. It also assimilates [high]. However, [high] is assimilated—as in Kimatuumbi—only if the stem vowel is [−low] (i.e., not /a/). Thus, as in Kimatuumbi, we postulate a harmony rule that spreads [high] to a directly following [−low] vowel on the right (cf. (48)). A separate rule also spreads [ATR] to the vowel on the right; unlike in Kimatuumbi, this second rule has no restrictions on its application.[20]

Although the proposed reanalyses need to be verified by further study, the evidence from Kimatuumbi and Kinande appears to provide no compelling arguments for Odden's reorganization of the feature tree.

At the end of the section devoted to motivating the Height node in (39) Odden briefly discusses the interesting assimilatory process of the Cameroonian language Esimbi. Odden's facts and analysis are taken from Hyman 1988, where it is proposed that the feature [ATR] is contrastive in Esimbi. According to Hyman (p. 260), Esimbi vowels reflect the four degrees of vowel height shown in (50).

[20] Kinande is also subject to a harmony rule that spreads [ATR] from right to left. This rule is responsible for the alternants of the /eri/ prefix. For some discussion of this harmony process see Clements 1991.

(50) a. i ɨ u = high vowels
b. e ʌ o = mid vowels
c. ɛ ɔ = low-mid vowels
d. a = low vowel

Hyman claims that these four degrees of vowel height cannot be characterized by means of the features [high] and [low]. Moreover, he states that the failure to distinguish four vowel heights makes it impossible to account for the complicated distribution of vowel qualities in Esimbi prefixes. To overcome these difficulties, Hyman introduces [ATR] as a contrastive feature in Esimbi. In many languages the phonetic differences in tongue height between /ɛ ɔ/, on the one hand, and /a/, on the other, are well attested. To mention but one of the languages discussed above, in Tunica /a/ has lower tongue height than /ɛ ɔ/ (as noted in Haas 1940:13, 15). However, this phonetic distinction is a pure "surface fact" in that it plays no role in the phonology of the language. The same is true of Esimbi, as is shown by the facts discussed below.

Esimbi has the nine vowels given in (51). The high back unrounded [ɨ] does not figure in the underlying representation of stems; it is a positional variant of underlying /a/ and /ʌ/. Thus, only eight of the nine vowels in (51) figure in underlying representations of Esimbi stems.

(51)

	i	u	ɨ	e	o	ʌ	ɛ	ɔ	a
high	+	+	+	−	−	−	−	−	−
low	−	−	−	−	−	−	+	+	+
back	−	+	+	−	+	+	+	+	+
round	−	+	−	−	+	−	−	+	−

In Esimbi words the stem vowel always surfaces as one of the three [+high] vowels. Moreover, in polysyllabic stems the vowels are identical. In prefixes, on the other hand, any of the vowels in (51) may surface except /ɨ ʌ/. The surface manifestation of both prefix and stem vowel is uniquely determined by the underlying height features of the stem vowel and, in the case of the prefix, by its morphological class. The facts of interest are summarized in (52), which reproduces Hyman's (1988) table II.

(52)

	Prefix:	I	U	A
Stem:	/i/	i-Ci	u-Ci	o-Ci
	/u/	i-Cu	u-Cu	o-Cu
	/e/	e-ci	o-Ci	ɛ-Ci
	/o/	e-Cu	o-Cu	ɔ-Cu
	/ʌ/	e-Cɨ	o-Cɨ	ɔ-Cɨ
	/ɛ/	ɛ-Ci	ɔ-Ci	a-Ci
	/ɔ/	ɛ-Cu	ɔ-Cu	a-Cu
	/a/	ɛ-Cɨ	ɔ-Cɨ	a-Cɨ

As seen in (52), there are three classes of prefixes, labeled with the letters *I, U, A,* which are taken here as diacritic markers. As noted already, the stem vowel always surfaces as [+high, −low], but the other features of its underlying representation are preserved. The underlying height features [high] and [low] of the stem vowel are reflected in different ways by the three classes of prefixes. In I- and U-prefixes the surface vowel is always [−back, −round], respectively [+back, +round], but preserves the other features of the underlying stem vowel. The underlying values of the features [low] and [high] do not appear intact in the A-prefixes. The correspondences are nonetheless straightforward, as shown in (53).

(53) A-prefix vowel:	/o/	/a/	/ɛ ɔ/
Underlying stem vowel:	[+high]	[−high]	[−high]
	[−low]	[+low]	[−low]

Esimbi speakers can therefore readily reconstitute the feature values of the underlying stem vowel: those for [back] and [round] surface on the stem vowel, those for [low] and [high] on the prefix. Thus, from an informational point of view the situation is only slightly less transparent than that encountered in a language where prefixes copy all features of the stem vowel.

Formally, these facts can be readily accounted for by positing that Esimbi prefixes assimilate all vowel features of the stem. A set of readjustment rules then modify the stem and the prefix vowels separately to produce the surface forms just reviewed.

The readjustment rules required consist of a stem rule and a set of prefix rules. The stem rule assigns the feature [+high] to the stem vowel, and where required, a repair rule supplies the feature [−low]. The I-prefix rule assigns the feature [−back], and where required, [−round] is supplied by a repair rule. Similarly, the U-prefix rule assigns the feature [+round], and where required, [+back] is supplied by a repair rule. This readjustment rule also applies to A-prefixes to which the [+high] feature has been spread from the stem. A-prefixes to which [−high] has been spread are assigned [+low], whereas [+high] A-prefixes are assigned [−high]. Since each of the readjustment rules assigns but a single feature, the Esimbi data provide, pace Odden, no argument for (or against) a specific feature tree. Moreover, the data provide no evidence for the placement of the feature [ATR] in the tree, since the inclusion of this feature in the readjustment rules—as proposed by Hyman—does nothing but obscure the nature of the phenomena.

This completes the discussion of the evidence adduced by Odden in support of the feature tree (39). If the reanalyses presented here are correct, all facts can be described equally effectively with the anatomically more natural feature geometry of (1).

5.2 Sequential Constraints on Consonants in Javanese

A feature organization different from both (1) and (39) was proposed by Steriade (1988): "Tongue body position in vowels and consonants is characterized by distinct articulator nodes. [high], [low], [back], specifications minimally necessary in most vowels, form a

constituent, Dorsal, which characterizes vowels and contrastive palatalization/velarization in consonants. Velar/uvular consonants have a distinct articulator node, Velar'' (p. 15).

Steriade motivates this proposal to supplement the Dorsal node in the feature tree with a Velar node by claiming that it is crucial for a reanalysis of Kenstowicz's (1986) account of certain processes in the phonology of Javanese. In this study Kenstowicz argues that the phenomena in question are special instances of the Obligatory Contour Principle (OCP) (see McCarthy 1986). To work out this proposal technically, Kenstowicz postulates that in Javanese consonants and vowels are represented on separate autosegmental tiers in the manner first introduced by McCarthy (1979) in an account of the Semitic inflections. As Kenstowicz remarks, however, Javanese is ''not like Semitic, where root consonants carry the basic lexical meaning of a word, while the vowels (as well as the CV patterns of a root) implement various tense-aspect markings or are otherwise stipulated by the word-formation rules of the language'' (p. 243). The decision to project vowels and consonants on separate autosegmental tiers is therefore much less securely motivated for Javanese than for Semitic. Moreover, as Kenstowicz also notes, his solution involves ''a serious violation of the inalterability conditions of Hayes 1984 [1986] and Schein and Steriade 1984 [1986].'' The review of these phenomena undertaken by Steriade was therefore clearly necessary.

Kenstowicz's paper focuses on two unrelated bodies of facts: certain rules affecting vowel features and their propagation to the vowel in the preceding syllable(s), on the one hand, and the restrictions on consecutive consonants in Javanese stems, on the other. By making full use of the resources provided by feature geometry, Steriade shows that the Javanese facts can be handled without tier separation and without violating inalterability in Schein and Steriade's formulation.[21]

Although Steriade's reanalysis of the facts is on the right track, it does not go far enough, for it fails to examine critically the Javanese facts that lead Kenstowicz to have recourse to the OCP. Kenstowicz invokes the OCP in his analysis of both the vowel rules and the consonant restrictions. Although Steriade fails to note this explicitly, her reanalysis of the vowel rules proceeds without recourse to the OCP, nor does it require her to postulate a Velar node in addition to the Dorsal node in the feature tree.

Since Steriade's reanalysis thus deals with the vowel facts in a manner that is compatible with the feature tree (1), nothing further will be said about these facts here. What follows is therefore focused exclusively on the restrictions on consonant sequences in Javanese stems. I argue that both Kenstowicz's and Steriade's attempts to account for these facts are flawed because they crucially involve implausible and unmotivated modification of the feature tree, and I suggest that these restrictions on consonant sequences are statistical phenomena that must not be reflected formally in an account of the phonology of the language. If this suggestion is correct, it invalidates Steriade's introduction

[21] Steriade's reanalysis is not compatible with Hayes's (1986) version of inalterability. It must, therefore, be taken as evidence against this version and in favor of the competing version by Schein and Steriade.

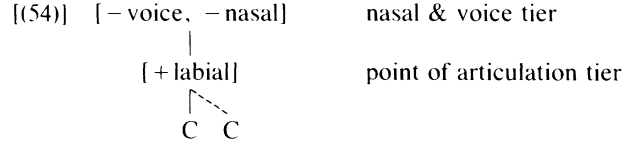
of the Velar node, since the consonant sequences constitute the sole motivation for this node.

Kenstowicz cites Uhlenbeck 1950 as the source for the observation that there are severe restrictions on consonant sequences in Javanese stem morphemes. "In particular," he writes, "there is a remarkable tendency for the first two consonants of a root to be either identical or to be drawn from different points of articulation" (p. 244). Consonants sharing the point of articulation are noticeably underrepresented in these positions. Thus, in a table of consonant sequences in roots excerpted by Kenstowicz from Uhlenbeck 1950, there are 41 instances of morphemes of the form /pVp . . . /, but only 1 instance of a morpheme of the form /pVb . . . / and 9 instances of /pVm . . . /.

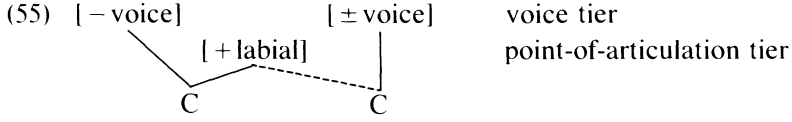
Kenstowicz attempts to reflect this observation in his formal account by invoking the OCP. He writes, "As John McCarthy 1985 [1986] . . . has recently observed for Semitic . . . [these] generalizations can be subsumed under the OCP if we assume that consonants are partitioned into dimensions that correspond to natural phonetic segmentations. In particular, if there is a separate point of articulation tier, the OCP will prohibit successive occurrences of the same point of articulation and require a multiple linking" (p. 245).

As Kenstowicz notes (p. 245), the implementation of this proposal requires a radical reorganization of the feature tree:

> In order for this result to hold for the Javanese data . . . we would have to assume that the features of voice and nasality link to the skeletal tier through the point of articulation tier. In this way successive *p*'s can be derived, but p-b and p-m, etc. blocked.



The modification of the feature geometry that is necessitated by Kenstowicz's account is not especially plausible, since it implies—contrary to what is perhaps the most securely established result in this domain—that point-of-articulation assimilation cannot take place without also involving the simultaneous assimilation of nasality and voicing. Yet without the modification of the feature tree Kenstowicz's account does not go through, because as illustrated in (55), if point of articulation and voicing (and nasality) are represented on separate tiers, the OCP implies that there should be no difference between sequences such as /pVp . . . / and /pVb . . . /.



According to Steriade (1988:14–15),

> [t]he non-cooccurrence of homorganic consonants morpheme internally can be characterized as Articulator-disharmony, the effect of [a] filter such as [(56)], which disallows adjacent instances of the same Articulator dominating identical specifications.
>
> [(56)] *. . . Articulator$_i$ Articulator$_i$ . . .
>
> Filter [(56)] is meant to rule out, among other things, tautomorphemic velars [i.e., velar consonants]. But if the articulator node of velars is the same as that of vowels [i.e., Dorsal] problems arise: first, there is no incompatibility between vowels and velars, suggesting at the very least that no vowel of Javanese has the underlying place specification of a velar consonant. Second, if vowels have Dorsal nodes, a [. . . gVK . . .] morpheme will incorrectly escape filter [(56)]: the two identical Dorsal nodes are not adjacent, because separated by the Dorsal node of the vowel.[22]

Thus, like Kenstowicz, Steriade is led to propose a modification of the feature tree in order to account for the Javanese constraint on consonant sequences. As we have seen, Kenstowicz's modification is unacceptable because it would make it impossible to account for the widely attested instances where Place assimilation is independent of the assimilation of voicing and nasality. Steriade's proposed modification is to introduce an additional articulator under the Place node, labeled Velar, whose role is restricted to consonants exclusively, the Dorsal articulator now being limited to vowels. The main objection to this proposal is that it undercuts the simple anatomical interpretation of the articulator nodes. By adding the Velar articulator node to the feature tree, we would be claiming in effect that a different anatomical structure is involved in the execution of the features [high], [back], and [low] than that involved in generating the closure in the velar and uvular consonants. And there is no evidence for such a claim.[23]

In view of this, a rethinking of the status of the Javanese constraint is in order. Recall that the sole function of the constraint is to account formally for the facts noted by Uhlenbeck. However, not every fact that can be discovered about a language is necessarily reflected in the formal account of the language, and this is especially true of statistical observations such as those made by Uhlenbeck. It is not the case that aspects of a language that are not rule-governed are always equally probable. Nor must every skewed distribution be attributed to the effects of a rule. For example, the distribution of the vowels /a/ and /i/ in the English vocabulary is surely not rule-governed, yet the vowels have vastly different statistical distributions.

The Javanese consonant restrictions under discussion are clearly facts of this latter kind. Since no evidence or argument has been presented to show that they interact with

[22] Steriade's assertion that if vowels have Dorsal nodes, a [. . .gVK. . .] morpheme will incorrectly escape the filter is strictly speaking not correct. Rather, if vowels have Dorsal nodes, the filter (56) will rule out any sequence of Dorsal consonant and vowel including [. . .gVK. . .].

[23] For arguments against some other attempts to introduce anatomically unmotivated modifications in the feature tree, see Halle and Vaux 1994.

any other part of the phonology, there is no reason to reflect them formally in the phonology. If these restrictions need not be reflected formally in the phonology of the language, then Steriade's constraint (56) has no place in a phonology of Javanese. Since the constraint was the sole motivation for the introduction of the Velar articulator node, the elimination of the constraint also eliminates the need for postulating the node. The same is true for the modification in the feature tree in (54) proposed by Kenstowicz. We may then conclude that the facts of Javanese do not constitute a challenge to the feature geometry in (1).

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