Place of Articulation in Consonants and Vowels: a Unified Theory

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1. The Organization of Place Features

This paper is concerned with the following question: what phonological features are required to characterize place of articulation in consonants and vowels? A significant result of recent work in feature theory has been the discovery that features are organized into subclasses which participate in phonological processes such as assimilation and deletion as a single functional unit. One way of accounting for such behavior is to group features into trees in such a way that all and only "natural classes" of features are constituents (see Clements 1985, 1987, 1991; Sagey 1986; McCarthy 1988, 1991, and others for general discussion). Among many other contributions, we owe to Sagey the notion of *articulator node*, designating the participation of an active articulator (the lips, the tongue front, the tongue body) in the production of a given segment, and to McCarthy the new feature *pharyngeal*, designating constrictions formed in the pharynx (broadly defined to include the larynx).

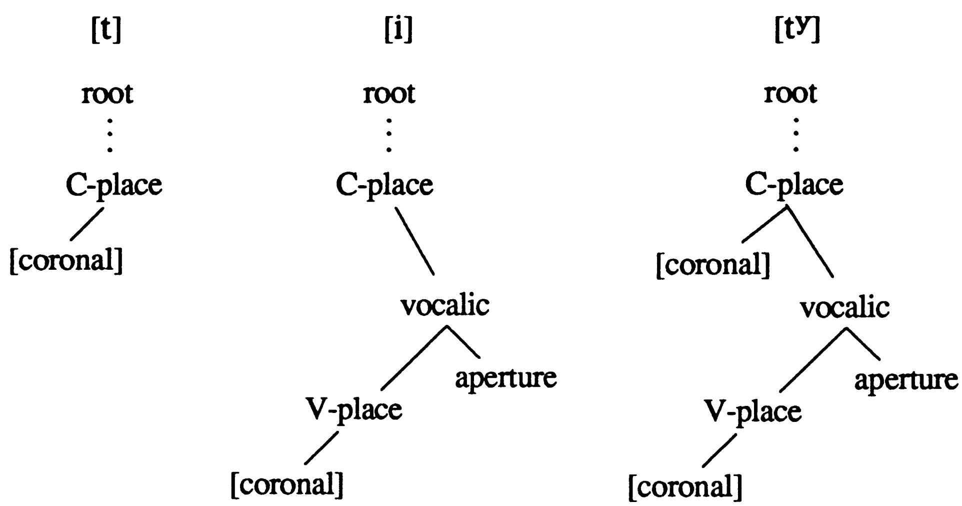
This study offers a contribution to two areas. First, departing from most current feature systems, it proposes that a single set of features characterizes place of articulation in both consonants and vowels. This set includes the oral cavity features *labial, coronal, dorsal* and possibly a pharyngeal cavity feature *radical* or *constricted pharynx*, located under the pharyngeal node. Under this proposal, features such as *back* and *round* become superfluous, and can be eliminated from feature theory. It will be shown that this simplification of the set of place features allows us to capture generalizations about the relations between consonants and vowels that earlier feature systems have failed to account for.

Second, this study offers a somewhat different model of feature grouping from that found in much other work. In particular, it proposes that place features of vocoids (i.e., vowels and glides) are partially segregated from those of consonants, in the sense that they are assigned to different regions or planes in phonological representation. Some amount of segregation of this sort is required to express the fact that place features of vowels and glides (which we informally term "V-place" features) spread more freely than place features of consonants (hereafter termed "C-place" features). For instance, it is well known that V-place features are not blocked by the presence of intervening consonants in processes of vowel harmony and assimilation.

Earlier work has expressed the relative freedom of vowels and glides by assigning different place features to consonants and vocoids, and arraying place features of vocoids on different tiers - and thus different *planes* - from place features of consonants (a phonological plane is defined by any two tiers whose elements can be linked by association lines). Thus, consonant place features such as *coronal* have been placed on one set of planes, and vocoid place features such as *back* on another. The present approach maintains a similar degree of segregation of place features, but uses the same set of features for consonants and vocoids. This requires that any given place feature must lie on a different plane according to whether it characterizes a consonant or a vocoid.

To illustrate, let us consider the partial representations of [t], [i], and palatalized [t^y] given in Figure 1 below.

Figure 1



As we see in the characterization of [t] at the left, primary place features of consonants, such as [coronal], are linked directly to the higher occurrence of the place node (informally called the *C-place* node). In contrast, as shown in the characterization of [i] at the center, place features of vowels and glides are linked to the lower of the two place nodes, termed the *V-place node*. These diagrams show that V-place features and C-place features are drawn from the same set *labial*, *coronal*, and *dorsal*, and differ only in where they occur in the tree. In the same way, the C-place and V-place nodes constitute the same formal category *place*, and differ only in their location in the tree. (We will continue to refer to them as the "C-" and "V-" place nodes as a matter of terminological convenience.) As the center diagram also shows, the V-place node links to the C-place node through an intermediate *vocalic* node, which also dominates vowel height features linked under the *aperture* node.

As we see at the right, a secondary articulation such as palatalization is represented by one or more V-place features. Thus palatalized [t^y] differs from plain [t] in having a V-place feature [coronal]. It is thus represented as the formal union of the feature trees characterizing [t] and [i]. (Like [i], it may also have vowel height features under the aperture node.) In this view, then, a secondary articulation is treated as the addition of a vocalic node to a consonant.

As far as primary place features of consonants are concerned, we provisionally adopt Sagey's definitions of the labial, coronal, and dorsal articulator nodes. Thus, a *labial* consonant involves the lips as an active articulator, a *coronal* consonant involves the tongue front, and a *dorsal* consonant involves the tongue body (Sagey, p. 274). In addition, *radical* (or *constricted pharynx*) designates a sound formed with a constriction in the lower pharynx (Perkell 1971). The node *pharyngeal*, to which *radical* links, designates any articulation formed in the pharyngeal cavity from the larynx to the uvula, and includes laryngeal sounds in some languages (McCarthy 1991).

In the model proposed here, which develops the preliminary work of Clements (1989) and Herzallah (1990) (see also related, independent proposals by Selkirk (1988), E. Pulleyblank (1989), Broselow and Niyondagara (1989) and Cheng (1989)), Sagey's feature definitions are extended to V-place features in the following way:

(1) (a) *labial* characterizes vowels produced with a constriction at the lips (rounded vowels)
(b) *coronal* characterizes vowels produced with a constriction of the tip, blade or front of the tongue (front and retroflex vowels as opposed to central and back vowels)
(c) *dorsal* characterizes vowels produced with a constriction of the center or back of the tongue, i.e. the palatine dorsum (back vowels as opposed to front and central vowels)
(d) *radical* characterizes vowels produced with a constriction in the lower pharynx (low and pharyngealized vowels); note that since [radical] links under [pharyngeal], any [radical] segment is necessarily also a [pharyngeal] segment.

It will be noted that the definition of *dorsal* given in (1) is different from Sagey's in a significant respect. In Sagey's view, a dorsal sound is simply one involving the tongue body as an active articulator in any capacity. In accordance with this view, the tongue body features *back, high,* and *low* are placed under the dorsal node, while *round* is placed under the labial node. An unfortunate consequence of this definition, however, is that we are no longer able to provide a uniform articulatory-based definition of *dorsal* for both consonants and vowels. In consonants, "dorsal" describes constrictions formed by the tongue body (as opposed to the tongue front, or the tongue root), and is used to characterize velars and uvulars. In vowels, however, "dorsal" does not necessarily designate a constriction at all. Thus, a low vowel such as [a] is treated as dorsal on grounds of its low tongue body position, even though its only constriction is located in the lower pharynx, as is shown by most x-ray studies (see e.g. Wood 1982). Similarly, the mid central unrounded vowel [ə] counts as dorsal even though it involves no displacement of the tongue body from the neutral position at all.

The present proposal restricts *dorsal* to sounds involving a constriction formed by the center or back (as opposed to the front) of the tongue, and thus distinguishes back vowels such as [u] or [ɑ] from central vowels such as [ʉ] or [a]. This proposal bring its definition into line with those of the other place features of vowels, which also designate constrictions. At the same time, we achieve a uniform definition of all place features in terms of articulator-defined constrictions (rather than articulator movements as such). This approach extends straightforwardly to consonants, since the articulator features also define constrictions in consonants, even though this is not directly entailed by Sagey's definitions.

We will see in the following discussion that this reinterpretation of articulator features allows a significantly improved account of natural classes of consonants and vowels. Some of the classes defined by this feature system are suggested in (2), which characterizes representative consonants and vowels in terms of the four features *labial*, *coronal*, *dorsal*, and *radical* (recall that the presence of [radical] in a segment implies the presence of [pharyngeal]).

(2)

	p	t/č	k	ʕ	i	u	ü	ɨ	e	o	ɛ	ɔ	æ	a	ɑ
labial	+				-	+	+	-	-	+	-	+	-	-	-
coronal		+			+	-	+	-	+	-	+	-	+	-	-
dorsal			+		-	+	-	-	-	+	-	+	-	-	+
radical				+	-	-	-	-	-	-	-	-	+	+	+

As this chart suggests, I provisionally assume that articulator features are one-valued in consonants and potentially two-valued in vowels (as well as glides and secondary articulations). That articulator features are one-valued in consonants has been suggested in recent work from Sagey (1986) onward, and is supported by the fact that rules which cause the negative values of these features to spread from one segment to another are rare, if not entirely unattested. As far as vowels are concerned, the features [back] and [round] have normally been treated as binary, and this assumption is tentatively carried over to the new use of articulator features as vowel place features; however, the binary nature of these features, too, may be open to question.[1]

Vowels are also distinguished by the aperture (vowel height) feature *open*, not illustrated here (see Clements 1990, 1991). As (2) shows, central unrounded vowels such as [ɨ] and [ə] have no place features in this system, and so from an articulatory point of view they are maximally unmarked (see also Kaye, Lowenstamm and Vergnaud 1985).

We will see in the following discussion that the proposed feature system makes a number of crosslinguistic predictions which are well supported on empirical grounds. First we look at a set of phonemic oppositions crucially involving the features *dorsal* and *radical* (section 2). We then consider a number of rules involving natural classes of vowels and consonants formed at the same place of articulation (section 3). Following this, we examine some of the predictions of the model regarding spreading rules and the locality constraints they are subject to (section 4). Finally, we examine a long-standing problem in feature theory, involving Swedish vowels (section 5). In all cases, we show that the present system captures linguistic generalizations in a way that most alternatives do not.

2. Phonemic Oppositions involving *Dorsal* and *Radical*

The redefinition of the feature *dorsal* given above predicts that we should find minimal phonemic oppositions between central and back vowels. A number of cases have been reported in the literature, which are reviewed below.

Oppositions between central rounded /ʉ/ and back rounded /u/ are reported in the Finnish dialect of Swedish, Woleaian (Micronesian), Tsou (an Austronesian language spoken in Formosa), and a group of closely related East Papuan languages including Nemboi, the Malo dialect of Nambakaengö, Nelua, Nooli, and Nanggu. (3) gives examples of the three high vowels /y ʉ u/ in Swedish, and full vowel systems for Woleaian, Tsou, and Nemboi.

(3) Vowel Systems with /ʉ/ and /u/:

Swedish (as spoken in Finland):

/y/: dyr 'expensive' /ʉ/: bur 'cage' /u/: bor 'lives'

Woleaian:

i	ʉ	u		ii	ʉʉ	uu
e		o		ee	ɵɵ	oo
	a				aa	ɔɔ

Tsou:

i	ʉ	u
e		o
	a	

Nemboi:

i		ʉ	u		ʉ̃	ũ
e			o			
ɛ	ö	ə	ɔ	ṏ	ə̃	
		a			ã	

Regarding Swedish, Kiparsky writes (1975, 170): "In the Swedish of Finland, the contrast [y] : [ʉ] : [u] ... may well have to be considered as one of front : central : back. Unlike what seems to be the case in Sweden, there are no significant differences in lip rounding between the three vowels". (Note that Kiparsky's vowel [y] is the vowel transcribed [ü] elsewhere in this paper; in general, I will use [ü] for high front rounded vowels and [y] for palatal glides to insure uniformity with most of my sources.)

In Woleaian, /ʉ/ (transcribed *iu*) is a high central rounded vowel, minimally distinct from the high back rounded vowel /u/ in both the short and long vowel series. Similarly, /ɵ/ (transcribed *eo*) is a mid central rounded vowel, differing minimally in the long vowel series from mid back rounded /o/ (Sohn 1975, 16-17).

In regard to Tsou, Tung states (1964, 19): "For the high central vowel, either of the two symbols "ɨ" and "ʉ" known in linguistic writings may be used. We choose the latter on the grounds that the average tongue position of the vowel is actually much nearer to /u/ than to /i/ and that it is in fact more or less rounded." Tung also argues for his analysis on grounds of economy, since it postulates two front, two central, and two back vowels.

In the East Papuan languages (represented here by Nemboi), central rounded /ʉ ʉ̃/ (transcribed *ü ü̃*) are reported to contrast with the corresponding back rounded vowels /u ũ/ in both the oral and nasal vowel series (Wurm 1970).

Phonemic oppositions between the high central and back unrounded vowels /ɨ/ and /ɯ/ appear to be rarer, which is not surprising in view of the relative markedness of back unrounded vowels. However, one such opposition is reported for Nimboran (a language of Western New Guinea) by Anceaux (1965). The full vowel system consists of the high vowels /i ɨ ɯ/, the mid vowels /e o/ and the low vowel /a/. /ɨ/, transcribed by Anceaux as *y*, is described as a "rather tense voiced high close central unrounded vocoid," while /ɯ/ (transcribed *u*) is a "voiced high close back unrounded vocoid" (pp. 13-15). Minimal pairs include /ki/ 'woman', /kɨ/ 'faeces', and /kɯ/ 'time, day'. That /ɨ/ and /ɯ/ are both high vowels is shown by the further fact that they pattern together with /i/ in a constraint allowing sequences of identical high vowels but not nonhigh vowels: thus, /ii ɨɨ ɯɯ/ are possible sequences while /ee oo aa/ are not. Furthermore, that [ɯ] and not [ɨ] is [dorsal] is shown by the existence of a morphologically-conditioned rule changing [b] to [g] after the velar nasal [ŋ] or postvocalic [ɯ], i.e. after high dorsal sounds. This rule, which is clearly assimilatory in nature, does not apply after /ɨ/.

Some languages are also known to use *radical* (or *pharyngeal*) in a contrastive fashion. These include the Lezgian (Caucasian) languages Tsakhur and Udi, in which each of the vowels /i u e o a/ (and /ɤ/ in Tsakhur) has a phonemically distinct pharyngealized counterpart (Catford 1983).

According to the x-ray tracings reproduced by Catford, the pharyngealized vowels are produced with two simultaneous constrictions, an anterior one involving the front of the tongue and a posterior one involving the root of the tongue near the tip of the epiglottis. In Tsakhur, the pharyngealized vowels all involve a higher F_1 frequency and all but the pharyngealized counterpart of /a/ involve a lower F_3. In addition, the pharyngealized front vowels have a lowered F_2 while the pharyngealized back vowels have a higher F_2, suggesting a centralization of the anterior lingual constriction. These data clearly show that a feature of pharyngeal constriction, associated with raising of the first formant, is required for vowels in addition to features of tongue height, coronality and labiality.

The features given in (4) seem to be adequate for Tsakhur vowels. As the descriptions do not make it clear whether [ɤ] is a central or back vowel, no value is assigned for [dorsal].

(4)

	i	e	a	o	u	ɤ	iˤ	eˤ	aˤ	oˤ	uˤ	ɤˤ
coronal	+	+	-	-	-	-	+	+	-	-	-	-
labial	-	-	-	+	+	-	-	-	-	+	+	-
dorsal	-	-	-	+	+	?	-	-	-	+	+	?
radical	-	-	+	-	-	-	+	+	+	+	+	+
open	-	+	+	+	-	+	-	+	+	+	-	+

To distinguish plain [a] from pharyngealized [aˤ], I assume that [pharyngeal] (dominating [radical]) is linked directly to the C-pl tier in the latter. This characterization is in conformity with the fact that the pharyngealized vowels are produced with considerable friction (J.C. Catford, p.c.). For further discussion of place features linked directly to the C-place node in vowels, see section 5.

3. Natural Classes of Consonants and Vowels

We now examine a wide range of phonological phenomena, including assimilation rules, dissimilatory constraints, strengthening and weakening processes, and secondary articulation, which give clear evidence for a feature system of this type. We will be especially concerned with examples in which vowels and consonants form a natural class at a single place of articulation, as defined by one of the articulator features *labial, coronal, dorsal* and the constriction region feature *pharyngeal.* Due to space limitations, we will consider only one example of each process type, but in nearly all cases, these are representative of a larger set of examples.

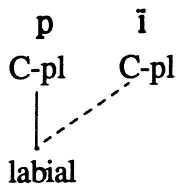
3.1. Spreading Processes

We first look at spreading (assimilatory) processes in which a vowel acquires the place of articulation of a neighboring consonant, or vice-versa. We will call these *cross-category* assimilations, since the spreading feature spreads from vocoids to consonants or vice-versa. Cross-category assimilations involving *labiality* are familiar from many studies, including the crosslinguistic surveys of Reighard (1972) and Campbell (1974). A further example can be cited from Tulu, a Dravidian language (Bright 1972). In this language, the high unrounded central or back vowel designated by the symbol [ī] is labialized if preceded either by a labial consonant, or by a rounded vowel in the preceding syllable (compare the first and second columns in (5)). This rule gives rise to regular alternations, as in the accusative suffix illustrated in the last example in the set.

(5) a.	nāḍī	'country'	b.	bolpu	'whitener'
	kaṭṭī	'bond'		kappu	'blackness'
	pudarī	'name'		uccu	[kind of snake]
	ugarī	'brackish'		moroḍu	'empty'
	ari-n-ī	'rice' (acc.)		ūru-n-u	'country village' (acc.)

This process involves the rightward spreading of the feature [labial] to the target vowel. What is of special interest is that it does not matter whether the spreading feature [labial] occurs on a vowel or a consonant. In the latter case, [labial] spreads from the C-place tier of the consonant to the vowel, as shown below:

(6)



We will see in the discussion of section 5 that articulator features such as [labial] may occur directly under the C-place node in vowels. Thus, the output of (6) is potentially a well-formed structure. On the other hand, it is possible that spreading rules of this type yield configurations in which a separate token of [labial] links directly to the V-place node of the vowel, giving the more usual configuration for vocoids. There seems to be no evidence that would allow us to decide between these alternatives in the case of Tulu.

We also find languages in which consonants acquire a primary labial articulation next to rounded vowels. For instance, this process occurs before the high rounded vowel /ụ/ in many Bantu languages, as shown by the following examples (from Guthrie 1967-71):

(7) *pụ, bụ, tụ, dụ, kụ, gụ > fu (zones K,L,M,N,S, e.g. Bemba M.42)
*pụ, tụ, kụ > fu, bụ, dụ, gụ > vu (Venda S.21)
*tụ, dụ, kụ, gụ > fu (Songe L.23)
*tụ > vu, dụ > bvu (Mvumbo A.80)
*kụ > fu (Punu (B.43, Swahili G.42, Sango G.61, Bembe H.11, Luyana K.31)
*kụ > βu (Benga A.34)

Capital letters occurring after the language names designate Guthrie's geographically-defined zones. As these letters indicate, labialization took place in widely scattered zones throughout the Bantu-speaking area, and appear to have involved several independent innovations. If this is true, we have good evidence that we are dealing with a natural phonological process.

We may characterize this type of assimilation in terms of the spreading of [labial] from the V-place node of the vowel to the C-place node of the consonant, where it displaces the original place feature, as shown in (8a).

(8)

(tụ → fu)

On current assumptions, however, which do not allow a node to be simultaneously linked to nodes on more than one other tier, the resulting configuration should be ill-formed. We might therefore assume that the spread of [labial] to the consonant requires the interpolation of new V-place and vocalic nodes in the consonant, creating secondary labialization (for the notion of interpolation, see Sagey 1986). The Bantu languages illustrated in (7) would then choose the additional (and presumably marked) option of promoting this feature to primary status under the C-place node, where it replaces the original primary features such as [coronal], as shown in (8b) (for the notion of tier promotion, see Clements 1989). Similar examples of tier promotion are discussed later in section 3.4.[2]

We turn next to cross-category assimilations involving *coronal*. In a number of languages, vowels are fronted next to coronal consonants. We illustrate with an example from Maltese Arabic, as recently discussed by Hume (1990). In Maltese, the underspecified imperfective prefix vowel, normally a copy of the following stem vowel (9a), is realized as [i] if the first consonant of the stem is a coronal obstruent (9b). Note that the underling stem vowels in *rifed* and *laħaʔ* are /i/ in both cases; in Hume's analysis, their surface quality results from a rule of I-lowering in the context __C# and a rule of Guttural Assimilation adjacent to a guttural, respectively.

(9)

	perfective	*imperfective*			*perfective*	*imperfective*	
a.	forok	yo-frok	'limp'	b.	daħal	yi-dħol	'enter'
	kotor	yo-ktor	'abound'		siket	yi-skot	'be silent'
	ʔasam	ya-ʔsam	'break'		žabar	yi-žbor	'collect'
	rifed	yi-rfed	'support' /rifid/		dalam	yi-ʃdlam	'to grow dark'
	laħaʔ	yi-lħaʔ	'reach' /liħiʔ/		čaħad	yi-čħad	'deny'

These examples can be understood as assimilatory if front vowels and coronal consonants are both characterized by [coronal]. If front vowels were characterized as [-back] as in traditional feature theory, these changes would appear to be arbitrary.

More commonly, consonants are frequently "coronalized" (i.e., realized with the coronal articulator) before front vowels as a result of palatalization rules. These rules may be viewed as assimilatory in nature if we treat front vowels as coronal (Clements 1976, Itô and Mester 1989). Particularly thoroughgoing examples can be found in the Bantu languages Kinyarwanda and Kirundi, where consonants at all places of articulation from labial to velar may receive a palatal or alveolar component before [yV] sequences arising from a variety of underlying /i + V/ sequences. The following examples are taken from Broselow and Niyondagara's study of Kirundi (1989).

(10) *Palatalization in Kirundi:*

a. labial stems:	*infinitive*	*perfective* /-i+e/	
'dry'	-kama	-kamye	(*my* = [mʲ])
'look at'	-raaba	-raavye	(*vy* = [vɟ])
b. alveolar stems:			
'play'	-kina	-kinye	(*ny* = [ɲ])
'do laundry'	-mesa	-meshe	(*sh* = [ç])
c. palatal stems: no change			
d. velar stems:			
'cook'	-teeka	-teetse	(*ts* = [tˢ])
'swim'	-oga	-ogdze	(*dz* = [dᶻ])
e. glottal stems:			
'go home'	-taaha	-taashe	(*sh* = [ç])

As Broselow and Niyondagara point out, if we characterize front vowels and glides as [coronal] we may state this rule as one that spreads the coronal node from the vocoid to the consonant. This node forms a contour with the original place node in the case of labials (10a), but totally replaces it in all other cases (10b-e), though vacuously in the case of palatals (10c).

Consider next the interaction of dorsal consonants and dorsal vowels. An interesting case of vowel dorsalization (with concomitant rounding) in the context of dorsal consonants has been described in Palestinian Arabic (PA) by Herzallah (1990). In Measure 1 of the verb (the derivational base class), we find two ablaut classes a/i and i/a defined by alternations in the last vowel of the stem; the first vowel of each class occurs in the perfective, and the second in the imperfective. (Note that PA has lost the underlying short /u/ of Classical Arabic.) Examples follow:

(11)	a. the i/a class:	*perfective*	*imperfective*
	'learn'	ʕilim	yi-ʕlam
	'regret'	nidim	yi-ndam
	'grow up'	kibir	yi-kbaṛ
	b. the a/i class:		
	'write'	katab	yi-ktib
	'trap'	ɦabas	yi-ɦbis
	'bewitch'	fatan	yi-ftin

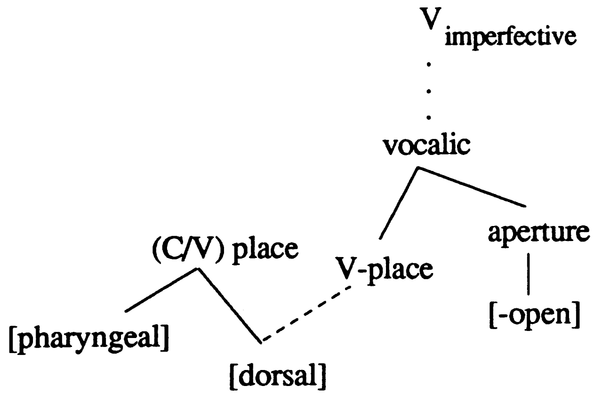
Herzallah accounts for stem ablaut by a morphological rule which requires the imperfective stem vowel to take the opposite value of the feature [open] from the perfective, i.e. [αopen, Perfective] → [-αopen, Imperfective]. However, she notes an exception to the pattern illustrated in (11b) just in case the root contains one of the emphatic consonants /ṭ ṣ ẓ ḍ ṛ/ or one of the uvulars /K x γ/, in any position. In this case, the stem vowel is replaced by [u] in the imperfective, as shown by the forms on the right:

(12)		*perfective*	*imperfective*
	'ask for'	ṭalab	yi-ṭlub
	'cross out'	šaṭab	yi-šṭub
	'betray'	γadaṛ	yi-γduṛ
	'kill'	Katal	yi-Ktul
	'get hot'	saxan	yi-sxun
	'excel'	nabaγ	yi-nbuγ

Herzallah argues, on the basis of a wide range of evidence, that what the emphatic and uvular consonants share to the exclusion of all other consonants (including velars) is a *dorso-pharyngeal* articulation characterized in terms of the two features [dorsal, pharyngeal]. This articulation is primary in the uvulars, secondary in the emphatics. She proposes that the feature [dorsal] spreads to the vowel, postulating the rule shown in (13) below. (This rule feeds a later redundancy rule, which rounds the high dorsal vowel: [+dorsal, -open] → [+labial].)

It is of particular interest that (13) applies regardless of whether [dorsal] is a C-place or a V-place feature. Thus, [dorsal] is a primary place feature in uvulars, occurring under the higher of the two place nodes (the C-place node), but a secondary place feature in emphatics, occurring under the lower of the place nodes (the V-place node). This rule supports our view, expressed earlier, that the C-place node and the V-place node are actually the same node, differing only in their position in the tree.

(13) [-open] Dorsalization (mirror image)



In other languages, dorsal vowels and glides trigger velarization of neighboring consonants. An interesting case of consonant/vowel interaction can be cited from Maxacalí, as described by Gudschinsky et al. (1970) and further discussed with respect to feature theory by Reighard (1972). Maxacalí has the phonemic vowels / i ï e o a / and their nasal counterparts, where / ï / is a high back unrounded vowel. In tautosyllabic VC sequences, an extra-short unstressed vowel V̆ is inserted before the consonant, agreeing with it in nasality. (The consonant itself is then deleted if it is homorganic with the following consonant.) These facts are illustrated below.

(14)	*if C is:*	*V̆ is:*	
	k / ŋ	ï / ï̃	(high back unrounded)
	c / ɲ	i / ĩ	(high front unrounded)
	p / m	ë / ë̃	(lower mid back unrounded)
	t / n	ə / ə̃	(central unrounded varying from low to high)

It will be observed that the epenthetic vowel is back, i.e. dorsal, before a velar consonant and front, i.e. coronal, before a palatal consonant. In other words, the epenthetic vowel agrees in place of articulation with a following high consonant.[3]

The epenthetic vowel itself triggers a further process of epenthesis, according to which the vowel cluster VV̆ is broken up by a glide or consonant whose place of articulation (and nasality) depends uniquely on the first vowel, as shown in (15). ([ɣ] is a voiced velar fricative.) The generalization here is that the inserted consonant or vowel agrees in the features [labial, coronal, dorsal] as well as [nasal] with the preceding vowel.

(15)	*if the first vowel is (oral or nasal):*	*then C is:*
	i (high front unrounded)	y / ỹ
	o (mid back rounded)	w / w̃
	ɨ (high back unrounded)	ɣ / ŋ
	a (low central or back unrounded)	ɣ / ŋ
	e (mid front unrounded)	(none)

In sum, the Maxacalí data in (14) and (15) offer further evidence for the patterning of dorsal consonants and back vowels together in a single [dorsal] class.

We finally consider a case of cross-category assimilation involving the feature [pharyngeal]. It is commonly observed that vowels lower in the context of pharyngeal consonants. For instance, in Palestinian [a] replaces the expected /i/ in the imperfective of the a/i ablaut class (cf. (11b)) next to one of the "gutturals" /x ɣ ħ ʕ h ʔ/.

(16)	*perfective*	*imperfective*
'resent'	saxaṭ	yi-sxaṭ
'stain'	maraɣ	yi-mraɣ
'butt'	naṭaħ	yi-nṭaħ
'deprive'	manaʕ	yi-mnaʕ
'rob'	nahab	yi-nhab
'ask'	saʔal	yi-sʔal

In her analysis of these facts, Herzallah (1990) follows McCarthy (1989b) in assuming that guttural consonants in Arabic are defined by the feature complex [pharyngeal, +approximant]. She proposes that [pharyngeal] spreads from C to V, where it triggers a bidirectional redundancy rule applicable to vowels: [+open] ↔ [pharyngeal]. If both pharyngeal spreading (16) and dorsal spreading (13) are defined on the same form, pharyngeal spreading normally takes precedence, as the first three forms in (16) demonstrate. However, roots like /sxn/ and /nbɣ/ in (12) are marked as exceptions to this rule and so undergo (13) instead.

3.2. Dissimilatory Constraints

We now consider evidence from another area, dissimilatory constraints. The importance of such constraints for the study of feature organization has been emphasized in recent work by Mester (1986), McCarthy (1988, 1991) and Yip (1989). These studies have strongly confirmed the view that *labial, coronal, dorsal* and *pharyngeal* define place of articulation in consonants. We will now see that feature cooccurrence constraints also support the extension of this set of features to vowels and secondary articulations, as proposed here. Evidence comes from cross-category constraints in which a place feature characterizing a consonant dissimilates from the same feature characterizing a vocoid, or vice-versa.

Let us consider [labial] first. An interesting set of cross-category dissimilatory constraints in certain Berber languages involves the labial consonants /b f m/, the labial vocoids /u w/, and the rounded consonants, /C^w/ (Selkirk 1988, Lasri 1990). These are summarized below:

(17) a. Any combination of two labial consonants {b f m} is prohibited within morphemes unless they are identical and either adjacent, or separated only by a vowel. Thus the sequences /bb/, /bVb/, /ff/, /fVf/, etc. are admissable, but all other sequences involving these three consonants are excluded.

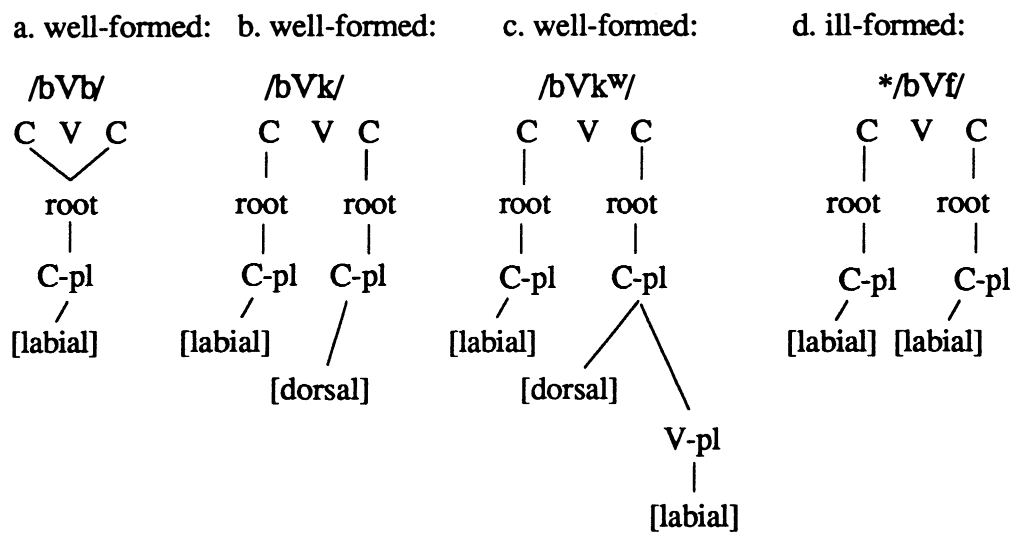
b. The combinations /C^wu/, /C^ww/, /uC^w/, /wC^w/ are excluded within morphemes.

c. Members of the set { C^w w u } combine freely with members of the set { b f m } within morphemes, except that /C^w/ is excluded immediately after {b m f}.

These patterns are not random, but reveal a dispreference for morphemes containing two labial or labialized segments, with distinctions depending on whether [labial] is linked to the C-place or the V-place tier. The most general constraints hold along single tiers: the C-place tier in the case of (17a), and the V-place tier in the case of (17b). The constraint involving two tiers is the least general of all (17c).

Following the essential insights of Selkirk and Lasri, we may account for these constraints in the following way. Let us assume that in Berber, the OCP excludes two adjacent occurrences of the feature [labial] on any tier. I will further assume, following McCarthy (1981, 1989a), that consonants and vowels are completely segregated in underlying representations in languages with template morphologies (for evidence that Berber has a template morphology, see Dell and Elmedlaoui, in press). Furthermore, in underlying representations in Berber, identical consonants are represented as multiply linked root nodes; no other multiple linkings are allowed. These properties are illustrated in the following underlying representations of the well-formed sequences /bVb/, /bVk/, and /bVk^w/ and the ill-formed sequence */bVf/, where V = any vowel. (In these simplified representations, vowel features, lying on independent and noninteracting planes, have been omitted).

(18)



In (18a), the multi-attached [b], describing the "long-distance" geminate [b...b], does not violate the OCP since it has only one occurrence of [labial] under the C-place tier. (18b) does not present a violation, since again, there is only one occurrence of [labial] in the representation. In (18c), although there are two occurrences of [labial], they occur in different substructures and thus do not violate the OCP. In (18d), however, the OCP is violated by two occurrences of [labial] on the same tier. Notice that we cannot merge these two occurrences of [labial] into one, on our assumption that only root nodes may be multiply linked in Berber.

At the level where tier conflation (see McCarthy 1986) has applied to fold consonant and vowel representations together, however, new violations of the OCP will arise wherever [labial] occurs in the representation of vocoids and consonants with secondary articulation. Thus the ill-formed examples in (17b) have representations such as that in (19a) at this level. Here, the OCP is violated under the V-place node.

Finally, consider violations of the type (17c), such as *[mk^w], which is illustrated in (19b). Here we see that the two relevant occurrences of [labial] lie in different substructures, yet the example is still ill-formed. To handle such cases, Selkirk proposes that we extend our account of the OCP so that it can generalize across tiers. She further suggests, however, that in order not to rule out the well-formed example (18c), all such generalized applications of the OCP must be subject to the condition that the affected segments are *adjacent* at the level of the the root tier. We will see further evidence for the correctness of this proposal in examples to be discussed just below.

(19) a. ill-formed: b. ill-formed:

In summary, then, examples like (19b) show that the same features (in this case, [labial]) are present under both the C-place and the V-place nodes, providing further confirmation for our hypothesis.

We will now turn to evidence showing that the feature [coronal] behaves in a parallel way to [labial]. According to Martin's account of Korean phonemics (1951), "the phoneme /y/ does not occur in syllables beginning with /t, c, s/ or including the vowel /i/" (p. 526). This constraint is actually more general, since all the coronal consonants /t t' t^h c c' c^h s s'/ and the vowel /i/ are systematically absent in /CyV/ syllables. /y/ is also excluded in these syllables with the vowels /e ε/. These constraints are shown in Martin's Table 3, relevant parts of which are summarized below (I substitute the more familiar symbol "ɨ" for Martin's "ə", and "ə" for his "ɔ"):

(20)

	CV								CyV								CwV							
	i	e	ε	ɨ	ə	a	u	o	i	e	ε	ɨ	ə	a	u	o	i	e	ε	ɨ	ə	a	u	o
p p' p^h:	i	e	ε		ə	a	u	o					ə	a		o		e						
t t' t^h:	i	e	ε	ɨ	ə	a	u	o									i	e	ε		ə	a		
c c' c^h:	i	e	ε	ɨ	ə	a	u	o									i	e	ε			a		
s s':	i	e	ε	ɨ	ə	a	u	o									i	e	ε		ə			
k k' k^h:	i	e	ε	ɨ	ə	a	u	o			ε		ə	a	u	o	i	e	ε		ə	a		
n l:	i	e	ε	ɨ	ə	a	u	o					ə	a	u	o	i	e			ə	a		
m h:	i	e	ε	ɨ	ə	a	u	o					ə	a	u	o	i	e	ε		ə	a		

We see that the palatal (hence, [coronal]) glide /y/ is excluded in any syllable containing a coronal obstruent or a coronal vowel (according to Martin, the syllables /kyε, k'yε/ constitute the only exceptions to this statement). As the table also shows, a similar constraint excludes the labial glide /w/ in any syllable containing a labial obstruent or a labial vowel (the syllables /pwe/ and /p'we/ constitute the only exceptions).

Under the present feature analysis, in which vowels, glides, and consonants are all characterized by the features [labial] and [coronal], we may conflate these two parallel constraints into a more general, OCP-driven one which excludes adjacent occurrences of the features [labial] and [coronal] in CGV syllables.[4] This statement, like the one given for Berber above, requires that the OCP must apply to adjacent identical features regardless of whether they occur under the C-place or the V-place tier. Thus the Korean data argue strongly that the same articulator features, in this case [labial] and [coronal], must be present in the characterization of consonants, glides and vowels alike.

A cross-category dissimilation involving [dorsal] appears to have taken place in the historical development of French (E. and J. Bourciez 1967, also noted by Reighard 1972). Between two vowels at least one of which was a rounded (i.e., labio-dorsal) vowel [u] or [o], the velar consonant [g] (representing not only original [g] but also secondary [g] derived from [k] by voicing) was weakened to [ɣ] and subsequently deleted. (As a regular exception to this principle, [ɣ] was palatalized before a front vocoid].) Also at an early stage in the history of French, the labial [β] from earlier [b] and [w] was deleted in the same context. These two processes are illustrated below (VL = Vulgar Latin):

(21)	a. [ɣ] > Ø / __ [u o]			b. [ɣ] > Ø / [u o] ___		
	sëur (> sûr)	<	securu	charrue	<	carruca
	fau (> fou)	<	fagu	rue	<	ruga
	lueur	<	VL lucore	jouer	<	jocare
	c. [β] > Ø / __ [u o]			d. [β] > Ø / [u o] ___		
	viorne	<	vibŭrna	nue	<	VL nūba
	dëu (> dû)	<	VL debūtu	[l]uette	<	VL ūvĭtta
	paon	<	pavōne	oeille (> ouaille)	<	ŏvĭcula

We may explain these deletions in terms of the OCP-driven elimination of adjacent specifications of the features [dorsal] (in (21a) and [labial] (in (21b) in VCV sequences. They thus offer a further example of a cross-category dissimilation.[5]

Cross-category dissimilations involving [pharyngeal] are rather hard to find, but this probably has to do with the fact that cross-category dissimilations and pharyngeal consonants are each quite rare taken individually, so that the combination of the two in one language should be even more unusual. One possible case is reported from Biblical Hebrew by Prince (1975), after the description in Lambdin (1971). The definite article, underlying /ha-/, normally triggers the lengthening of the initial consonant of the stem to which it is prefixed, as shown in (22a). But if the initial consonant is one of the gutturals, it is normally short and the vowel of the article is lengthened instead (22b). This fact can be explained if we assume that gutturals are lengthened by the regular rule and then shortened by an (independently-motivated) rule of guttural degemination, accompanied by compensatory lengthening of the preceding vowel. As a regular class of exceptions, however, if the guttural is [h] or [ḥ], the vowel of the article fails to lengthen (22c), and is raised to [e] if long [ā] follows in the stem (22d). The vowel of the article is also short and raised before stems beginning with the sequence [ʕā] (22e).

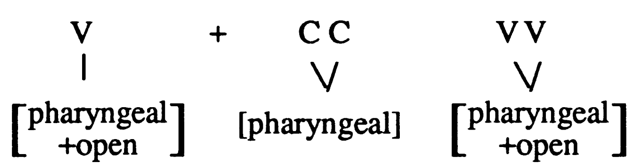
(22)

	indefinite	*definite*	
a.	báyiṯ	ha-bbáyiṯ	'house'
	náʕar	ha-nnáʕar	'youth'
	mélek̲	ha-mmélek̲	'king'
b.	ʔîš	hā-ʔîš	'man'
	ʕîr	hā-ʕîr	'city'
	rāʕā́ḇ	hā-rāʕā́ḇ	'famine'
c.	hēk̲ā́l	ha-hēk̲ā́l	'palace'
	ḥéreḇ	ha-ḥéreḇ	'sword'
d.	hārîm	he-hārîm	'mountains'
	ḥāk̲ām	he-ḥāk̲ā́m	'wise man'
e.	ʕārîm	he-ʕārîm	'cities'
	ʕāp̄ā́r	he-ʕāp̄ā́r	'dust'

Prince proposes that in cases of type (c)-(e), the gutturals actually do lengthen as expected, but that [h], [ḥ] and [ʕ] before [ā] regularly fail to undergo the normal degemination rule after the article /ha-/. A rule of Guttural Dissimilation then shifts short [a] to [e] before the geminate guttural + [ā] sequence as shown in (d)-(e). Prince cites further evidence suggesting that this rule applies elsewhere in the phonological system as well. (The intermediate geminates are shortened by a later rule which does not induce compensatory lengthening.)

That the rule creating [e] is dissimilatory seems clear, but it is less clear whether the guttural consonant or the low vowel triggers the dissimilation. The best answer seems to be that both do. Prince analyzes the short vowel system as consisting of underlying /e o a/, which I interpret in terms of the feature [open], giving a distinction between the open vowel /a/ and the nonopen /e/ and / o/. If we adopt the redundancy rule [+open] ↔ [pharyngeal], as proposed earlier for Arabic in connection with (16), the low vowel will be assigned the feature [pharyngeal], giving us the following (simplified) representations of the forms in (c)-(e) at the point where Guttural Dissimilation is defined:

(23)



Guttural Dissimilation deletes [pharyngeal] (and thus presumably [+open]) in the prefix vowel, which is raised to [e] by a further redundancy rule which requires nonlow nonlabial vowels to be front. The point here is that for Guttural Dissimilation to apply, *both* the following consonant and vowel must be [pharyngeal], creating a cross-category condition for dissimilation. If, in contrast, we did not assume that low vowels are [pharyngeal], we would be unable to explain why the raising of [a] to [e] is triggered only by pharyngeal consonants, as opposed to any other randomly-selected set.

In sum, we see that cross-category dissimilatory constraints provide a further source of evidence for the unity of place features in consonants and vowels. They also provide further support for Selkirk's suggestion that such constraints are restricted to segments which are adjacent at the root tier, since all our examples conform to this restriction. (Interestingly, there appears to be no parallel restriction on cross-category assimilation rules, since as we saw earlier, Dorsal Assimilation in Palestinian transmits [dorsal] from a consonant to a non-root-adjacent vowel in examples such as *yi-ṭlub, yi-Ktul* in (12). A similar case of non-root-adjacent, cross-category assimilation has been observed in Dravidian. In one Tulu dialect, a labialization rule similar to the one exemplified in (5) applies from a labial consonant to a following vowel *across* an intervening nonlabial consonant: *īmḷu* 'kind of leech', *avṭu* 'out' (Bright 1972).)

3.3. Strengthening and Weakening

A further prediction of the present system is that place of articulation will be preserved under processes which strengthen vocoids to consonants, or which weaken consonants to vocoids. We have assumed that in the usual case, place features of [+consonantal] segments link to the C-place node, and place features of [-consonantal] segments link to the V-place node (see Figure 1). Thus when a process of strengthening changes a vowel or glide to a consonant, its place features should automatically relink to the C-place node, and when a weakening process changes a consonant to a glide or vowel, its place features should relink to the V-place node. We examine a number of cases illustrating [labial], [coronal] and [dorsal] below.[6]

Labial vocoids (e.g., the labiovelars [u] and [w]) commonly strengthen to labial consonants. Thus, for example, the Latin glide [w] strengthened to [β], which later shifted to labiodental [v] in several modern Romance languages (Meyer-Lübke 1890):

(24)	*Latin* [w]	*Italian* [v]	*French* [v]	*Spanish* [b]	*Portuguese* [v]
	vinu [winu]	vino	vin	vino	vinho
	venit	viene	vient	viene	vem
	voce	voce	voix	voz	voz

In German, both historically and in some analyses synchronically, the fricative [v] derives from the glide [w] in words like *schwer* /ʃwe:r/ 'heavy,' realized [ʃve:ə] (Reighard 1972, note 2). Similar strengthening of labial glides to labial consonants took place in Sanskrit and several modern Indian languages, as well as Pekinese Mandarin, Finnish, Latvian, Scandinavian, and several Amerindian languages, to name a few (Campbell 1974, E.G. Pulleyblank 1989).

Similarly, labial consonants commonly weaken to labial glides and vowels. For example, in Romance languages, /b/ sometimes weakens to [w] and [u], as we see in Spanish (b > u syllable-finally in e.g. *ausencia* 'absence,' Campbell 1974), Picardese French (b > w, Reighard 1972), Rumanian (b > u / __ liquid, Nandris 1963, 111). Swahili [b] regularly weakened to [w] in forms like *watu* < **bantu* (Guthrie 1967-71). Few linguists will quarrel with these generalizations; indeed, changes like those cited in this and the preceding paragraph have provided some of the earliest motivation for extending the feature [labial] to consonants and glides. But parallel arguments can be given for [coronal] and [dorsal], as we will now see.

Palatal vocoids strengthen to palatal consonants in many languages. Thus in the development of Latin, the glide [y] commonly strengthened to a voiced fricative or affricate in syllable-initial position, parallel to the strengthening of [w] seen above (Meyer-Lübke 1890). Examples are given below, where Italian *gi* is the affricate [dʒ], French and Portuguese *j* is the fricative [ʒ], and Spanish *y* varies from [y] to a palatal fricative [ʐ] or stop [ɟ] dialectally:

(25)	*Latin*	*Italian*	*French*	*Spanish*	*Portuguese*
	iam [ya(m)]	già	(dé)ja	ya	ja
	iugo	giogo	joug	yugo	jugo
	iacet	giace	gît	yace	jace
	iuvene	giovine	jeune	(joven)	joven

We find similar processes at work in Bantu, again in widely scattered zones (Guthrie 1967-71):

(26) *y > dʒ (Kwakum A. 91)
*y > z (Boma B.82, Kwangari K. 33, Su<u>b</u>iya K.42)
*y > ɟ (in radicals) (Yao P.21)

A somewhat different source of strengthening can be illustrated in some varieties of Igbo, where sonorants nasalize in the context of nasal vowels through a process of progressive nasal spreading. This process is illustrated by the following sentence, due to Peter Ihionu (p.c.):

(27) a. o kwe we le ye 'he has begun to sing it'
he sing incep. perf. it
b. o kwẽ ŋʷẽ nẽ ɲẽ 'he has begun to stake it up'
he stake incep. perf. it

The full set of oral/nasal pairings is given below:

(28)							
	oral:	l	r	y	ɣ	w	h
	nasal:	n	r̃	ɲ	ŋ	ŋʷ	h̃

We see that the palatal glide [y] strengthens to the palatal nasal [ɲ], the dorsal [ɣ] strengthens to the dorsal nasal [ŋ], and the labiovelar [w] strengthens to the labiovelar nasal [ŋʷ].

Similarly, palatal consonants commonly weaken to palatal glides and vowels. Thus Proto-Bantu *ɟ frequently weakens to the glide [y], as shown below:

(29) *ɟ > y (Duala A. 24, Nzɛbi B. 52, Tɛgɛ-Kali B.71a, Tiene B. 81, Bobangi C. 32, Ndandi D. 42, Rundi D. 62, Tikuu G.41, Mbundu R.10, Kwanyama R.21)
*c/ɟ > ɦ/y (Herero R.31)
*ɟ > y ~ ɟ (Mpongwe B. 11a)

Many similar examples can be cited.

It is less commonly recognized that anterior coronal consonants (dentals and alveolars) can also weaken to coronal glides, perhaps because the palatal [y] is the commonest coronal glide crosslinguistically, and is the only coronal glide that commonly arises through regular processes of glide formation. However, [ɹ], a weakened form of [r], has been analyzed as a semivowel in English on the basis of the fact that it patterns with other semivowels and occurs phonemically as a syllabic sound (Kahn 1976), and [ɹ] may have a similar analysis in other languages.

Consider next the feature [dorsal]. Labio-velar vocoids strengthen not only to labial consonants, as shown in (24), but also strengthen to velar stops, supporting the inclusion of [dorsal] among the place features shared by consonants and vocoids. In Romance, Meyer-Lübke notes that "la consonantification de *u̯* ... revêt trois formes. Si l'articulation des lèvres, c'est-à-dire l'élément labial prévaut, il se produit un *v* ou une *f* ... Si, au contraire, c'est l'articulation vélaire qui l'emporte, *u̯* passe à *g*, *k* ..." (1890, 257). Examples of the latter process include:

(30) u̯ > g: Catalan *regna* < Lat. *reuna*, *sigró* < (older) *ciuró*
Italian *pagura* (alt. of *paura*) < *pau̯ora* < Lat. *pavore*
u̯ > k: Engadine Rhetian *kokr* < *kowr* < Lat. *cor*

Note also the development of [ɣʷ, gʷ] from the glide [w] in modern Spanish, where e.g. *huevo* 'egg' < Lat. *ōvum* has the frequent dialectal variants [weβo] ~ [ɣʷeβo] ~ [gʷeβo] (Navarro Tomás et al. 1970). Since [w] ultimately derives from a back rounded vowel in all these cases, the fact that it strengthens to velar fricatives and stops offers strong support for an analysis in which back vowels are assigned the feature [dorsal], as our analysis claims.[7]

Velar consonants are also reported to weaken to velar vocoids [w, ɰ]. In Maxacalí, /k/ weakens to either an unreleased stop [k˺], a velar fricative [ɣ ~ x], or a high back semi-vowel [ɰ] in utterance-final position (Gudschinsky et al. 1970). In many languages, including French (cf. (21)), Spanish, Turkish, and Kahe (Bantu E. 64), [ɣ] weakens and deletes in intervocalic or postvocalic position; it is possible that this process involves a intermediate velar glide [ɰ], though as this glide is seldom phonemic, it may not always be recognized in standard descriptions.[8]

In some cases, [k] and [g] weaken to the the palatal glide [i̯], in apparent contraction to our predictions. For example, in Western Romance (including Spanish), [k] and [g] are replaced by [i̯] in preconsonantal position in the groups [ks, kt, kl, gl, gn], as shown e.g. in the change from Vulgar Latin *pectināre* to Sp. *peinar* 'to comb' (Penny 1991). If the following consonant was syllable-initial it was normally palatalized, and the resulting sequence fused into a single coronal; thus, for example, we find [kl] > [i̯l] > [ʒ] (> [x]), as in Vulgar Latin *oc(u)lu* > Sp. *ojo* 'eye', as well as *nocte* > *noche* [notʃe] 'night' by a similar course. In other contexts, however, velars followed the normal course of lenition through intermediate [ɣ] to Ø, as in *lēgāle* > *leal* 'loyal.' As replacement of [k, g] by a palatal glide does not appear to represent a common crosslinguistic pattern, this development should probably be regarded as idiosyncratic.

3.4. Secondary Articulation

A further prediction of the present feature system concerns secondary articulation. Configurations of the sort given in Figure 1 predict that for each primary articulation type (labial, coronal, dorsal, pharyngeal) there should exist a corresponding secondary articulation type. This prediction is true. Thus, in his survey of 317 languages, Maddieson finds that "appropriate segments can have secondary articulations of the following types: labialization, palatalization, velarization, pharyngealization" (Maddieson 1984, 37). Not only do we find each of these simple secondary articulation types, we also find examples of *complex* secondary articulations combining two simple articulations. Representative examples are given below.

(31) *features:*	*secondary articulation:*	*example:*
labial	labialization/rounding	Akan
coronal	coronalization/palatalization	Slavic
dorsal	velarization	Ponapean
pharyngeal	pharyngealization	NE/NW Caucasian
labial + dorsal	labio-velarization	Irish
dorsal + pharyngeal	dorso-pharyngealization (emphasis)[9]	Arabic
labial+pharyngeal	labio-pharyngealization	Ubykh
etc.		

The fact that most or all of the predicted secondary articulation types are actually attested provides a strong new source of support for a unifed theory of place features.

Moreover, we occasionally find processes in which secondary articulations are *promoted* to the status of a primary articulation, in some cases replacing the original primary articulation. The present system predicts that place of articulation should be preserved in such cases: thus, when rounding is promoted it should be realized as a primary labial articulation, palatalization should be realized as a primary coronal articulation, and so forth.

Again, this is amply confirmed by an examination of cases. For example, the rounded velars [k^w g^w] commonly evolve into primary labial articulations. In a number of West African languages, we find the historical sequence *ku > kw > k^w > kp, accounting for at least some cases of the labiovelar stops found widely throughout West Africa (Ponelis 1974). The stops /p k k^w kp/ are represented as follows in the present system (note that all these stops are present and phonemically contrastive in some languages, such as Gã):

(32)	p	k	k^w	kp
C-place:				
labial	+	-	-	+
dorsal	-	+	+	+
V-place:				
labial			+	

The shift of [k^w] to [kp] involves promotion of secondary [labial] in the V-place structure to primary status in the C-place structure. In other cases, the promoted secondary feature totally replaces the original primary feature by a principle of complex segment simplification. In Indo-European, for instance, *k^w, *g^w commonly shift to simple bilabial stops, as in PIE *k^w > Greek [p] before back vowels and Latin [k^w, g^w] > Rumanian [p, b]. We find a parallel development of fricatives in the historical development of Ewe, where *χ^w shifted to the bilabial fricative [ɸ] and *$ʁ^w$ to its voiced counterpart [β] (Capo 1991). In all of these cases, the promotion of the secondary feature [labial] causes the original primary feature [dorsal] to delete through a process of complex segment simplification.

Turning to the feature [coronal], palatalization processes can often be treated as involving two stages, the second of which involves promotion. In stage I, vowel features spread to a neighboring consonant, creating a secondary articulation, e.g. [ki] > [k^yi], [ti] > [t^yi]. In stage II, the secondary articulation of the consonant is promoted to a primary articulation: [k^yi] > [c^yi], [t^yi] > [c^yi]. Subsequent developments may further affect the outputs by shifting the place of articulation of palatal obstruents to the less marked alveolar or palato-alveolar region, or by weakening stops and affricates to fricatives. Just such an account of palatalization in Korean dialects is given by Hume (1989), who shows that coronal stops first acquire secondary coronality from a following front vowel and then promote this feature to primary status, the resulting segment then merging with the underlying palato-alveolar series.

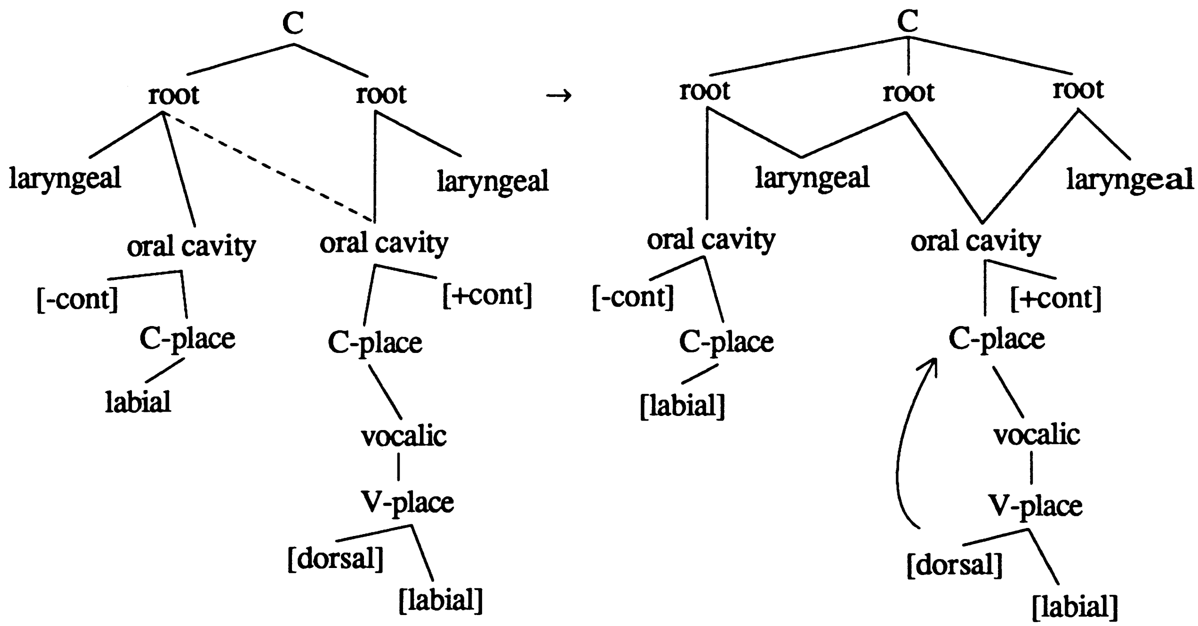
Consider next the promotion of the feature [dorsal]. In the Bantu language Venda, when the glide [w] (derived from underlying /u/) follows a bilabial stop or fricative, it triggers the introduction of an intrusive velar fricative which agrees with the stop or fricative in nasality, voicing, glottalization and aspiration (Ziervogel 1967). Some examples are given below:

(33)

			active	*passive* /-w-/
p^hw	→	px^hw	-p^hap^ha 'stick to'	-p^hapx^hwa
p'w	→	px'w	-t'ap'a 'beat off'	-t'apxw'a
bw	→	bɣw	-goba 'weed'	-gobɣwa
mbw	→	mbɣw	-βumba 'mould'	-βumbɣwa
mw	→	(m)ŋw	-luma 'bite'	-lu(m)ŋwa
ɸw	→	xw	-βoɸa 'fasten'	-βoxwa
βw	→	ɣw	-d̲iβa 'know'	-d̲iɣwa

What does this process consist of? The generalization appears to be that the intrusive segment preserves the place of articulation and continuance of the following glide, but assimilates to the preceding consonant in all other features. In a hierarchical feature framework, this process must be characterized in terms of the spreading of a single node. One candidate for this node is the oral cavity node, which dominates the place features and [continuant]. In an independent study of intrusive stop formation in English and Bantu, it has been shown that intrusive segments may be created by the rightward spreading of the oral cavity node from one segment onto the next (Clements 1987). A similar type of process might be at work in Venda, except that in Venda, the spreading must be leftward, rather than rightward, as shown in the first part of Figure 2: [10]

Figure 2



p^h w → px^{hw} w

I assume that the branching structure created under the root node on the left, constituting a highly marked configuration, is subject to a fission convention which causes the node to split into two (see Clements 1990). This is shown on the right in Figure 2, where the first two root nodes result from fission. Here, however, if we assume that major class features are properties of a higher node, such as the root node (McCarthy 1988), the resulting "intrusive" segment will be characterized as a consonant with no primary place features of its own. If we further assume, following a proposal by Halle (1989), that a nonvocoid (true consonant) must have at least one primary place feature, the secondary feature [dorsal] must be shifted to the C-place node of the fricative as shown by the arrow to ensure a well-formed output. As the examples in (33) also show, subsequent adjustments must apply to the output of this rule, turning derived nasal consonants into stops, and deleting the first root node before a nasal (optionally) or a fricative (obligatorily). This analysis directly accounts for the fact that the intrusive segment acquires its oral cavity features (place and continuance) from the segment on its right and all other features (nasality, sonorance, and laryngeal features) from the segment on its left. Whether this is the correct analysis of Venda, and whether it can be generalized to further languages, must await a more detailed study than can be undertaken here.[11] It seems clear, however, that whatever the exact analysis turns out to be, these processes exemplify promotion of the secondary feature [dorsal] in the glide to primary status in the intrusive consonant.

3.5. Summary

We have seen a wide range of evidence from several independent phenomena supporting the view that vowel and consonant place features are drawn from the same set of four: [labial], [coronal], [dorsal], and [pharyngeal]. In feature theories not unifying vowel and consonant place features in this way, the evidence for consonant and vowel patterning cited above is unexpected and fortuitous, and must be accounted for in terms of special, otherwise unnecessary rules and/or principles rather than directly in terms of the feature system itself. To the extent that they are required to do this, they appear to be less satisfactory as general theories of linguistic sound structure.

4. Constraints on Spreading

Let us now consider the formal organization of consonant and vowel features suggested in Figure 1. In this model, as the reader will recall, primary place features of consonants are linked directly to the C-place node, while place features of vowels (and secondary articulations) link to a lower node, the V-place node. This arrangement predicts that place features in vowels and consonants, forming different branches of the feature tree, should exhibit a high degree of phonological autonomy.

Let us consider the nature of the predictions made by this model more closely. The postulation of a nonterminal (or class) node *n* in a feature tree predicts that *n*, together with the features it dominates, may spread as a single unit in phonological rules. However, by the No Crossing Condition (34), spreading is blocked if an association line lies in its path:

(34) *No Crossing Condition (NCC)*
Association lines may not cross on a plane.

(Each tier is said to define a *plane* with its immediately superordinate tier, that is, the tier to which associations are allowed.) One type of evidence for the class nodes proposed in Figure 1 therefore consists of rules that spread these nodes as units. Another consists of the nodes which act as blockers, since the same nodes that spread in some circumstances will act as potential blockers in others. (There are of course further types of evidence, which will not be discussed here.)

This section examines evidence from both of these two sources. Section 4.1 considers spreading rules as evidence for the class nodes proposed in Figure 1, and section 4.2 considers the configurations which *block* the spreading of class nodes.

4.1. Spreading Rules

Let us now review evidence showing that the nodes proposed in Figure 1 can spread as single units. The present discussion concerns the C-place node and the vocalic node.

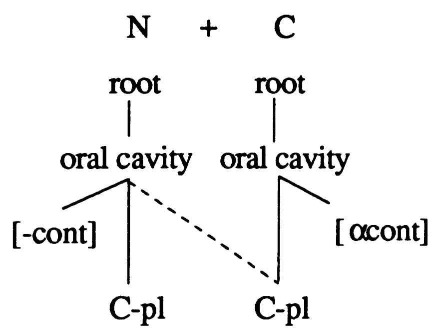
(Evidence for the aperture and V-place nodes has been presented in Hyman (1988), Odden (1989) and Clements (1990), and will not be repeated here.)

That the *C-place* node spreads is well attested in studies of common processes such as nasal assimilation, in which nasals assimilate to the place of articulation of following (or less often, preceding) consonants (see Goldsmith 1981). In Yoruba, for example, the progressive prefix is a nasal consonant whose place of articulation depends on the following consonant, as shown below (Ward 1952, 21):

(35)	[m] precedes [b f]:	mba, mfɛ
	[n] precedes [t d s ʃ n l r j y]:	nta, nda, nsa, nʃa, nlɔ, nri, nja, nyo
	[ŋ] precedes [k g w]:	ŋkɔ, ŋgun, ŋwa

These examples show that the nasal assimilates to the place, but not to the continuancy of the following consonant. This follows in the present model from the fact that stricture features like [continuant] are placed higher in the tree than the C-place node. Thus they are not affected by the spreading of the C-place node below them, as is shown below:

(36)

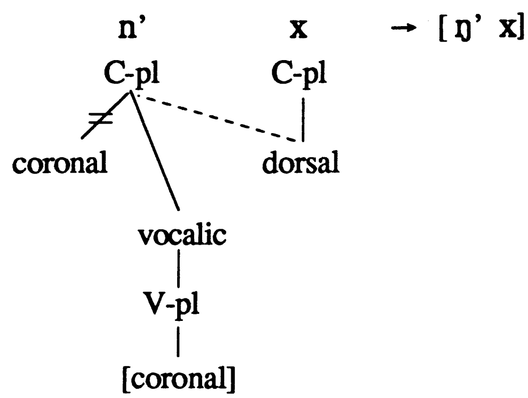


The model further predicts that articulator features under the C-place node can spread from one segment to another without entailing the loss of the secondary articulation features in the second. This, too, is borne out by the evidence. Thus in Modern Irish, as described by Ni Choisáin (1991), the assimilation of a palatalized coronal nasal to a non-palatalized dorsal segment usually retains the palatalization. In the following examples, the orthographic form is given on the left, and the phonetic transcription in the center:

(37)	<u>cinn</u>	k'i:n'	'ones'
	<u>na cinn chorcra</u>	nə k'i:ŋ' xorkrə	'the purple ones'

In the first form, the nasal is distinctively palatalized. When this nasal precedes the non-palatalized velar fricative [x], the dorsal node of the latter spreads leftward, replacing the coronal node of the nasal by a principle of complex segment simplification (cf. the discussion following (32) above). The loss of the coronal node does not entail the loss of the secondary articulation of palatalization, however, which is characterized by features located under the vocalic node. The process is illustrated below:

(38)



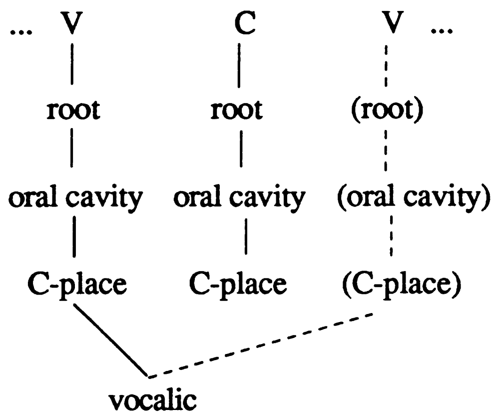
These facts follow directly from the present model.[12]

We next consider evidence for the vocalic node. Since the vocalic node dominates all place and aperture features in vowels, we expect to find languages in which all these features spread as a single unit. A number of languages give evidence for this prediction, and one will be discussed here. In Kolami (Emenau 1955), a rule of Vowel Insertion breaks up a root-final cluster of two consonants if it is word-final or is followed by a consonant in the same word, as is shown in the first two columns of (39a). In all cases, the inserted vowel is an exact copy of the preceding vowel. If these conditions do not hold (that is, if the cluster is followed by a vowel in the same word), Vowel Insertion does not apply, as we see in the third column. Vowel Insertion is blocked if the cluster is homorganic (39b).

(39)		*imperative*	*past*	*present*	*UR (root)*
a.	'break'	kinik	kinik-tan	kink-atun	/kink/
	'fill'	ninḍip	ninḍip-tan	ninḍp-atun	/ninḍp/
	'make to get up'	suulup	suulup-tan	suulp-atun	/suulp/
	'shake'	melep	melep-tan	melp-atun	/melp/
	'sweep'	ayak	ayak-tan	ayk-atun	/ayk/
b.	'boil over'	poŋ	poŋk-tan	poŋg-atun	/poŋg/
	'bury'	mind	min(t)-tan	mind-atun	/mind/

To account for these facts, we will assume that Vowel Insertion inserts an empty V-slot and spreads the vocalic node onto it from the preceding vowel, as shown in Figure 3 below:

Figure 3

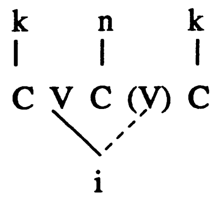


Parenthesized nodes are created by a general interpolation convention (Sagey 1986). As Figure 3 shows, the vocalic node can spread across the intervening consonant since the consonant is not characterized by a vocalic node of its own, and so cannot create a violation of the NCC (34).

Feature models lacking the vocalic node cannot account for these facts as successfully. Suppose one were to propose, for example, that it is not the vocalic node that spreads, but the C-place node, and that intervening consonants are underspecified for this node at the time spreading takes place. This analysis would require that spreading takes place only across a predictable place of articulation, such as velars, or anterior coronals, since thie appropriate place feature would have to be filled in later by a redundancy rule. In fact, however, spreading applies across *all* places of articulation, including labial, dental, and retroflex. Examples of spreading across labials include *tupuk* 'gun', *tupkul* 'guns', and *tupukt* 'onto the gun', from the basic form /tupk/, and similar examples. It is not possible to predict the place of articulation of the intervening consonant, which must therefore (at least in some cases) have a C-place node.

Another possible analysis might view Kolami vowels and consonants as completely segregated in planar structure, following McCarthy's (1989a) analysis of Arabic, Mayan and other languages, as well as with the analysis of Berber proposed above. In this view, if a language has a thorough-going template morphology (as do Arabic and Berber) or a fixed root template (as does Mayan), the template is omitted in the underlying representations of lexemes. When it is introduced derivationally, consonants link to it on one family of planes and vowels link to it on another (nonintersecting) one. At this point, consonants and vowels are entirely segregated in phonological representations, and are brought together only by the later process of tier conflation which "folds" the consonant and vowel planes together. If we analyzed Kolami in this way, vowel copy could apply entirely within the vowel space prior to tier conflation, as is shown below for *kinik*:

(40)



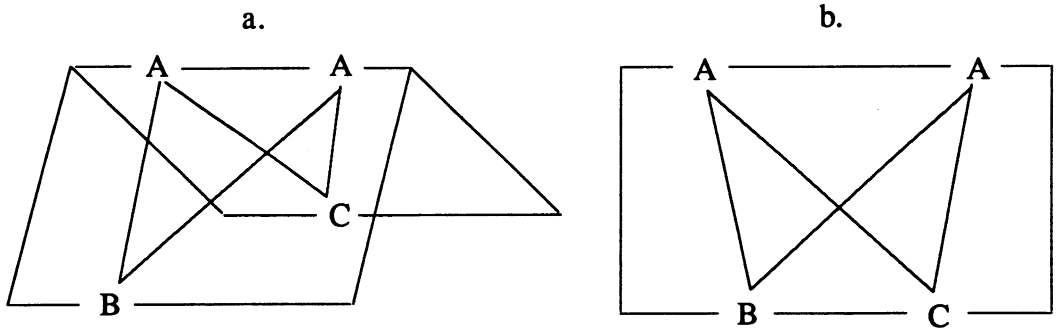
The option of total consonant/vowel segregation must be used with care, since its unconstrained use predicts many rare or nonoccurring patterns of spreading. For example, used freely it would predict that *all* consonant features can spread as a unit across all intervening vowels. However, while long-distance consonant assimilation of this type is a well-known phenomenon in languages with template morphologies, it is seldom if ever found in languages with purely concatenative morphological systems. In Kolami, for example, there are no rules of total consonant assimilation across vowels, and there is no other evidence for total consonant and vowel segregation. This is not surprising, since Kolami does not meet McCarthy's criteria for the lexical omission of CV templates: it does not have a template morphology, and its roots have a variety of CV templates such as CV, VC, CVC, VCC, etc. It seems, then, that the vocalic node provides us with just the degree of freedom that we need to account for the facts of Kolami without making incorrect predictions. The vocalic node hypothesis allows segregation just where it is needed, to account for the spreading of vowel features across consonants in languages which do not otherwise show evidence of total segregation.[13]

4.2. Bounding Conditions on Spreading Rules

An adequate theory of feature organization must not only be able to predict the nodes that spread together, it must also predict which nodes block spreading. The organization suggested in Figure 1, together with the NCC (34), makes a number of predictions in this respect which turn out to be well supported by the evidence. We consider some of them below.

Recall that by the NCC, association lines may not cross on a plane. The NCC does not exclude configurations in which lines appear to cross on the two-dimensional representation of separate planes, as shown in Figure 4a below, but it does rule out the monoplanar crossing shown in Figure 4b:

Figure 4

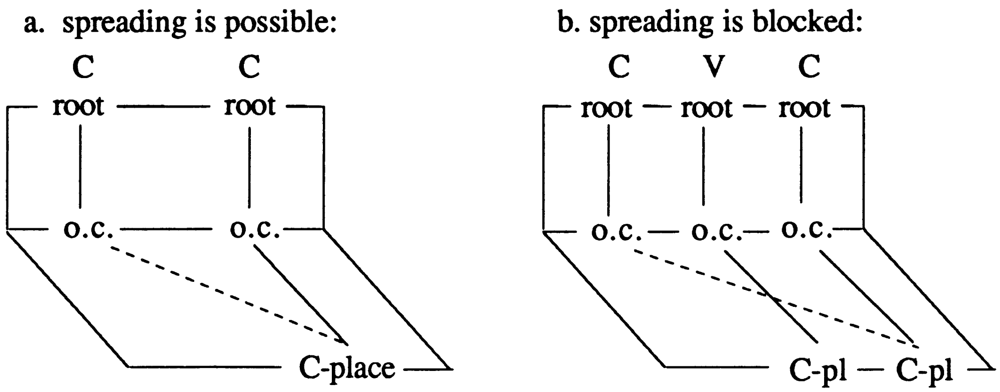


The NCC is *inviolable* in the sense that not only are configurations like Figure 4b disallowed underlingly, they cannot be created (and subsequently repaired) derivationally.

A first prediction of the model is that rules of total place assimilation in consonants will be restricted to consonants which are immediately adjacent to each other; an intervening vowel or consonant will block them. This is because the node which spreads in such rules is the C-place node (cf. (36)); since most consonants and vowels have a C-place node, they will act as blockers as long as they are specified for the C-place node at the point at which the spreading takes place.

The blocking effect of intervening segments is illustrated in Figure 5 below. We see that spreading is possible in a CC sequence (Figure 5a), but blocked in a CVC sequence (Figure 5b), where it would create line-crossing on a single plane:

Figure 5



This type of blocking is widely confirmed. Thus we commonly find rules in which nasals assimilate to the place of articulation of an adjacent consonant, as expressed informally in (41a), but we do not find rules in which nasals assimilate to a nonadjacent consonant, across a vowel or consonant, as in (41b,c).

(41) a. [nasal] → [αplace] / __ [αplace]
b. [nasal] → [αplace] / __ V [αplace]
c. [nasal] → [αplace] / __ C [αplace]

This fact is explained by the NCC and the node structure of Figure 1, as illustrated in Figure 5. It provides evidence that vocoids are characterized by a C-place node, since it is this node that creates a violation of the NCC in Figure 5.

A further prediction of the model is that rules spreading the vocalic node will not be blocked by "plain" consonants, that is, consonants without secondary articulations. This prediction is verified in the Kolami examples in (39); since (plain) consonants are unspecified for a vocalic node, they do serve as blockers, as was shown in Figure 3.[14] Thus the model correctly predicts that while rules of total place assimilation may only affect adjacent consonants, rules spreading the vocalic node may apply freely across intervening consonants.

On the other hand, if spreading takes place at a higher node in the tree, such as the C-place node or the root node, we expect *all* consonants to act as blockers to vowel assimilation rules; in such cases, vowel assimilation will be restricted to adjacent vowels. In fact, many languages do restrict total vowel assimilation rules in this way. In Luganda, for example, the first vowel in a VV sequence, if nonhigh, totally assimilates to the second, while VCV sequences are unaffected (Clements 1986):

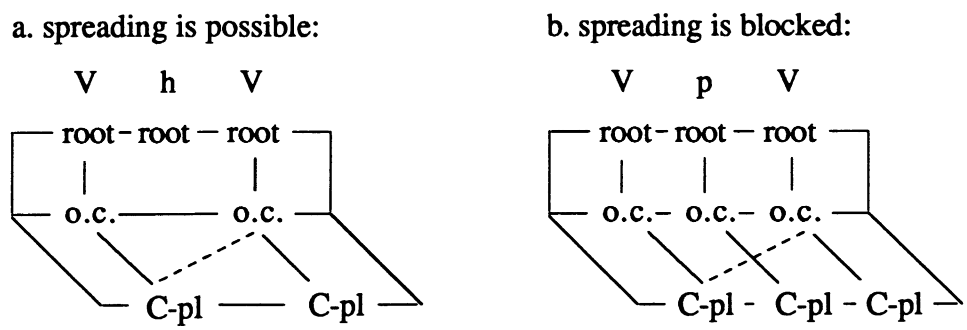
(42)	ka+oto → [kooto]	'fireplace' (diminutive)
	ka+ezi → [keezi]	'moon' (diminutive)
	ekikopo ekio → [ekikopeekyo]	'that cup'
	ateme omuti → [atemoomuti]	'let him cut the tree'
	cf:	
	na+koze [nakoze]	'I worked' (*[nokoze],*[nakeze],*[nekeze], etc.)

If we state the spreading rule as one that applies to the C-place (or root) node, we directly account for the blocking effect of intervening consonants.

A further prediction of the model is that if a segment lacks the oral cavity node, it will be transparent to rules spreading the oral cavity node or any lower node, such as the C-place node. One case of this type can be found in languages having vowel assimilation rules which, though otherwise restricted to adjacent vowels, cross any intervening laryngeal glide [h, ʔ]. As Steriade (1987) has pointed out, such "laryngeal transparency" can be made to follow under the assumption that laryngeal glides are characterized only by laryngeal, and not supralaryngeal features. Under such an analysis, laryngeals have no oral cavity node, and so cannot serve as blockers to rules spreading e.g. the C-place node.

This is shown schematically in Figure 6 below. 6a illustrates the transparency of the laryngeal glide [h] to a rule spreading the C-place node from one vowel to another, while 6b shows the opacity of the consonant [p].

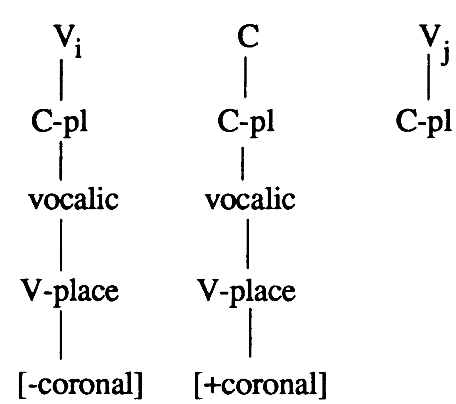
Figure 6



This rule will have the effect of spreading all the place and aperture features of the vowel to an adjacent vowel across an intervening laryngeal, but not any other consonant, as we find in Acoma, Mohawk and Nez Perce.[15]

A further prediction of the node structure suggested in Figure 1, and the last one we will discuss here, is that consonants bearing a secondary articulation feature of category [F] will block the spread of either value of feature [F] from a vowel. This is because secondary articulation features of consonants are assigned to the same set of planes as place features of vowels: namely, the planes subordinate to the vocalic tier. For example, the spread of [-coronal] in a vowel will be blocked by a secondary articulation feature [+coronal] in a following consonant since the latter is opaque on the plane defined by the V-place and [F] tiers. This situation is illustrated below.

Figure 7



Here, [-coronal] is prevented from spreading from V_i to V_j due to the specification of [+coronal] on the same plane. We cannot circumvent this obstacle by spreading the V-place, vocalic, or C-place nodes, since these nodes, too, are followed by nodes of the same category on the same plane. Thus in its most general form, the node structure assumed here predicts that secondary articulations will block the spreading of any and all vowel features of place and aperture across them.

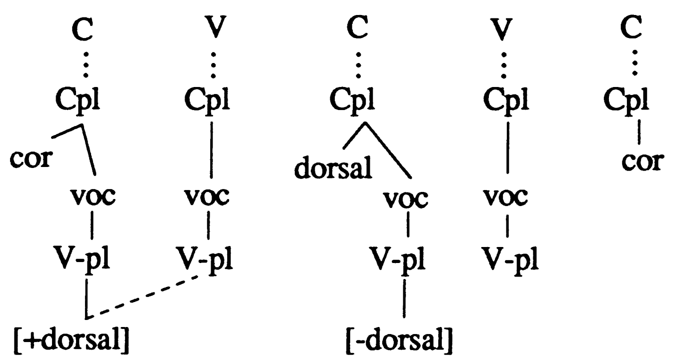
There is a certain amount of evidence in support of this prediction, and we will consider one example from Chilcotin, an Athapaskan language described by Cook (1983, 1987). In Chilcotin, consonants fall into three underlying series, "sharp", "flat", and "neutral." Vowels fall into two underlying sets, full (tense) /i u æ/ and reduced (lax) /ɪ ʊ ɛ/. By a rule of Flatness Spread, all vowels acquire "flattened" (that is, lowered and backed) realizations when they precede or follow one of the flat sibilants (/dẑ tŝ tŝ' ŝ ẑ/) or flat velars (/G q q' x̣ ɣ/ and their rounded counterparts), either immediately or when separated by one or more neutral consonants. Thus, for example, /i/ is flattened to [ᵊi] or /e], /u/ to [o], /ɛ/ to [ə], /æ/ to [ɑ], and so forth under these conditions, as shown in (43a). Furthermore, just in case the triggering consonant is a flat sibilant, this rule affects not only a following reduced vowel (if there is one) but a full vowel in the next syllable (43b). However, spreading to this syllable is blocked by any sharp consonant such as /g k'/, as is shown in (43c).

(43)	a. /ŝitin/	[ṣᵊitin]	'I'm sleeping'	
	/niŝdẑun/	[neṣḍzon]	'owl'	
	/ŝdli/	[ṣdlᵊi]	'pants'	
	b. /ŝɛɬtin/	[ṣəɬtᵊin]	'he's comatose'	
	/tɛ-ŝɛ-dæh/	[tə-ṣə-dah]	'I've sat down'[16]	
	c. /ŝɛgɛn/	[ṣəgɛn]	'it's dry'	*[ṣəgən]
	/nædiŝk'æn/	[nadeṣk'æn]	'it's burning again'	*[nadeṣk'an]

Let us consider how this blocking effect can be explained. Following the essentials of Cook's analysis, we may view the sharp consonants as opaque segments, specified for a feature which blocks the transmission of flatness to their right. What might this feature be? According to Cook (1983), who compares the "flat" sounds of Chilcotin to the emphatic sounds of Arabic, the flat sibilants have a locus (i.e., estimated second formant target value) of 1000 Hz, while the sharp sibilants have a locus of 1500 Hz. In addition, the point of contact is denti-alveolar for the sharp sibilants and post-alveolar for the flat ones. These facts, together with the observation that the flattened vowels are retracted toward the center of the vocal tract, suggest that the flat and sharp sounds are distinguished at least by contrary specifications for a secondary feature [dorsal], and perhaps for other features as well.[17] Thus flat consonants are [+dorsal] under the vocalic node, sharp consonants are

[-dorsal], and neutral consonants are unspecified for any secondary articulation at all. In examples like those of (43c), once [+dorsal] has spread onto [ɛ], further spreading is blocked by the specification of [-dorsal] on the sharp consonant to its right. For example, /ŝɛgɛn/ would have the partial representation shown in Figure 8, excluding the dashed line:

Figure 8



The dashed line shows the application of Flatness Spread to the first vowel. At this point, since the opaque specification of [-dorsal] on the next consonant is on the same plane as [+dorsal], it blocks its spread to the second vowel by the No-Crossing Constraint (NCC).

This analysis depends on the assumption that the articulator features are binary under the vocalic node (see (2) above). There is independent evidence for this assumption in Chilcotin. A rule of Strident Assimilation causes sharp sibilants to become flat if a flat sibilant follows in the word, and flat sibilants to become sharp if a sharp sibilant follows in the word, thus changing the value of [dorsal] in both directions. Neutral consonants (including neutral sibilants) are excluded from the process, as are flat velars (at least when the trigger is a flat sibilant). This process is illustrated below (Cook 1987):[18]

(44)	underlying:		Strident Assimilation:		Flattening:	
	sɛ-u-ẑɛ-nɛ-ɬ-tŝæn	→	ŝuẑinɬtŝæn	→	[ṣoẓᵊiɬtṣ'an]	'you listened to me'
	næ-ŝɛ-i-ɬ-ts'ɪl	→	næ-si-ɬ-ts'ɪl	→	[næsiɬts'ɪl	'I'm curling my hair'

This rule shows that [dorsal] behaves in a binary fashion. As the second examples also show, Strident Assimilation crucially precedes Flattening, since vowels have their normal (unflattened) realizations in the context of sharp sibilants derived from underlying flat ones. But if Strident Assimilation precedes Flattening, the flatness feature (i.e., [dorsal]) must also be binary at the point when Flattening applies.

The examples discussed in this subsection are primarily designed to illustrate the way in which bounding conditions on spreading rules can give evidence for node structure. While further research may show that some of this structure should be modified or even abandoned, current evidence suggests that the node structure illustrated in Figure 1 together with the NCC accounts quite well for a wide range of bounding conditions across languages.

5. Swedish Rounded Vowels

Swedish vowels have presented a long-standing challenge to feature theory, which we will address in this section.

Any feature system must be able to provide an account of the two distinctive types of rounding found in Swedish, sometimes called "in-rounding" and "outrounding." Earlier systems were forced to introduce two features, [labial] and [round], to account for these vowels. Here we review the facts, and show that the present system accounts for the distinction between these two types of rounding in a natural way, without requiring use of the additional feature [round].

Swedish has four phonemically contrastive high vowels, [i: y: ʉ: u:], of which the first three are front and the last three labial. The problem is to distinguish [y:] and [ʉ:], which are both front and labial. The difference between them concerns the nature of labialization: the "out-rounded" vowel [y:] involves lip protrusion, while the "inrounded" vowel [ʉ:] involves narrow approximation without protrusion.

The feature system of SPE, which provided only the feature [round], was unable to distinguish these two vowels. To remedy this defect, Fant (1969, 1971) proposed the feature [labial] to designate sounds produced with extreme lip closing and an extreme lowering of all formants, as shown below:

(45)

	i	y:	ʉ:	u:
labial	-	-	+	+
round	-	+	+	+

However, Fant observes further facts about these vowels which suggest that this analysis is not quite correct.

Fant finds that all four long vowels involve a diphthongal movement toward articulatory closure and back to a more open phase, effected by tongue body movement in the case of [i: y:] and by lip narrowing in the case of [ʉ: u:]. He remarks:

> It has long been recognized that all Swedish long vowels of extremely low first formant frequency, [i:], [y:], [ʉ:], and [u:], are pronounced as diphthongs towards a homorganic glide or fricative. However, what is not so obvious and often overlooked is that the vowel [y:] is made with a palatal closing gesture just

as in [i:] but with added lip-rounding and that the front vowel [ʉ:] is produced with a labial gesture towards closure just as in the back vowel [u:]... At the place of the vowel target the main constriction is at the lips for [ʉ:] and [u:] but at the tongue-palate region for [i:] and [y:]. (Fant 1973, pp. 183-4)

In accordance with Fant's account, narrow I.P.A. transcriptions of [i: y: ʉ: u:] represent them as the closing diphthongs [i:(j), y:(ɥ), ʉ:(β), u:(β)] in which the parenthesized element is usually described as a voiced fricative (see e.g. Malmberg 1966). These observations are further supported by the fact that the secondary palatal closure of [ʉ:] is generally more open than that for [y:] while the secondary labial closure of [y:] is less extreme than that for [ʉ:] (Fant 1969, 1971). Thus, the Swedish high vowel system is a symmetrical one, pairing two extremely palatal vowels with two extremely labial vowels.

Given these further observations, it is apparent that the feature description given in (45) is still inadequate, as it fails to express the symmetrical nature of the long vowel system. A solution is possible, however, within a feature system that distinguishes between primary and secondary functions of the articulator features. Specifically, let us assume that the extreme closing gesture of the Swedish high vowels results from the fact that these vowels have a consonantal component, which we express by assigning the appropriate articulator feature to the C-place node. Thus the extremely palatal vowels [i:], [y:] will have [+coronal] under the C-place node, while the extremely labial ("inrounded") vowels [ʉ:], [u:] will have [+labial] under the C-place node. Features realized with a lesser (i.e., typically vocalic) degree of constriction are represented in the V-place structure. This gives us the following symmetrical characterization of Swedish high vowels:

(46)

	i:	y:	u:	ʉ
C-place:				
labial			+	+
coronal	+	+		
V-place:				
labial	-	+		
coronal			-	+

This characterization directly captures Fant's insight that the main constriction is palatal for [i: y:] and labial for [u: ʉ:].

This analysis is justified by the fact that it accounts for two independent observations at the same time. First, it directly accounts for the fact that the high vowels of Swedish (unlike those of most other languages) are produced with a consonantal closing gesture. This results from the fact that each has a primary or C-place articulator feature, which must be produced with the minimum degree of closure required for consonants. Second, it explains the fact that the closing gesture for labial vowels involves lip narrowing rather than lip protrusion. This follows from the fact that this is the normal articulatory interpretation of [+labial] in C-place structure. Thus, the analysis fits the facts quite well, and gives a good basis for phonetic interpretation.[19]

We see, then, that Swedish vowels give further evidence for the assignment of place features to two separate "channels" in phonological representations. In vocoids, articulator features are normally linked to the V-place node, but may be assigned to the C-place node when extremely narrow offglides are involved, as in Swedish. In consonants, articulator features are normally linked to the C-place node, but may also be linked to the V-place structure when they describe secondary articulations, such as labialization or palatalization.

6. Summary and Discussion

The unified theory of place of articulation presented here, in which the features *labial, coronal, dorsal,* and *radical* (the latter a dependent of *pharyngeal*) characterize place of articulation in both consonants and vowels, has led to a number of desirable results.

First, it has allowed an internal simplification of feature theory by unifying the definition of *dorsal* in consonants and vowels, and eliminating the superfluous features *back* and *round.*

Second, it allows a direct characterization of a number of phoneme contrasts that cannot be readily described in most alternative systems, involving minimal distinctions between central and back vowels and between plain and pharyngealized vowels.

Third, it accounts for the widespread evidence that consonants and vowels fall into natural classes on the basis of a small set of articulator features. These features are: *labial*, which assigns labial (bilabial, labiodental, labiovelar) consonants to the same class as rounded vowels; *coronal*, which groups together all coronal consonants together with front (and retroflex) vowels; *dorsal*, which groups velar, labiovelar and uvular consonants with back vowels; and *radical*, which classes "deep" pharyngeal consonants with low and pharyngealized vowels. Evidence for these classes comes from a wide variety of phonological phenomena including assimilation rules, dissimilatory constraints, and strengthening and weakening processes.

Fourth, it projects directly to the attested secondary articulations of labialization, coronalization, velarization, and pharyngealization, and correctly expresses the interaction of secondary articulation features with both vowel place features and primary consonant place features.

Fifth, it accurately predicts which classes of features spread as units in phonological rules, and which classes of features block the operation of spreading rules.

And sixth, we have seen that this system offers an improved account of a traditional problem in feature theory, involving the characterization of Swedish vowels.

A number of other interesting issues have not been dealt with in this paper, and deserve further study. One involves the tree affiliation of the features *radical* and *pharyngeal*. The present study has assumed, with McCarthy (1989, 1991) and Herzallah (1990), that these features attach under the place node, though this assumption has not been crucial to any of the discussion. This assumption may be in need of reconsideration. For example, it is still not clear whether these features spread together with oral articulator features in rules of total place assimilation. In a possible alternative view, one might attach these features at a higher level in the tree, where they are not dependents of the place node (for one such suggestion, see Halle 1989). The present study leaves this question open, but does show that in any adequate treatment, "deep" pharyngeal consonants must be related to low and pharyngealized vowels.

Another question that has not been adequately explored in this study involves the valence of place features. We have followed Sagey's view that the place (or articulator) features of consonants are one-valued, and have found no evidence to the contrary in the data discussed here. On the other hand, the extension of articulator-based features to vowels raises the question of whether vowel place features should be treated as one-valued as well, contrary to the standard view. In some recent theories (e.g. Schane 1984, Anderson and Ewan 1987), vowel features (termed "particles" or "components") are strictly one-valued. Moreover, recent work in underspecification theory (see Archangeli 1986 and references therein) has tended to suggest that vowels are underlyingly specified for [-back] and [+round] but not [+back] and [-round], although this trend has not been given any special theoretical status in the theory. Translated into the system proposed here, this result would suggest that vowels are usually specified for the positive values of [coronal] and [labial] but not the negative values. This evidence would, of course, be compatible with the strong view that these features are always one-valued, as has recently been reasserted by van der Hulst (1989). Again, full exploration of this question would go beyond the scope of the present study.

Consider, finally, the interpretation of this model at the phonetic level. As we have seen, the model proposed here does not use a partly disjoint set of place features for consonants and vowels (as do more familiar models, such as that of Sagey (1986)), but employs a single, smaller set for both. By reducing the number of features available to phonological representation while maintaining a universal system of node organization, the model provides a highly constrained and strongly predictive account of the ways in which consonants and vowels can interact with each other. At the phonetic level, it claims that the same system of articulators is used in the production of all segment types, but that the articulator-defined constrictions will vary in degree of stricture (and possibly other characteristics) according to whether they are involved in forming a consonant or a vowel. Thus, for example, in consonants the feature [labial] is normally interpreted as lip approximation or closure, while in vowels it is normally interpreted in terms of lip protrusion. These differences are not arbitrary, but relate to the fact that the labial closing gesture is used to shape a resonator in vowels, but to obstruct the airstream in consonants.

While the labial closing gesture is therefore necessarily different in character in each case, the same articulators (the lips) are used for both segment types. The linguistic evidence shows that this fact is directly encoded in phonological representations, by requiring the feature [labial] to be assigned to consonants and vowels alike. Similar remarks can be made in regard to the other articulator features, whose identity across consonants and vowels is also well supported by the phonological evidence. The view that emerges from this system is that a single, uniform set of phonological parameters is involved in consonant and vowel representation, but that these parameters are projected onto separate planes where they receive context-dependent interpretations at the phonetic level.

The set of features proposed here converges to some extent with recent work by Wood (see e.g. Wood 1982), who arrives at a similar feature system primarily on the basis of the study of articulatory data, rather than phonological patterning. A shared set of articulators for consonants and vowels, also similar to the one proposed here, is assumed in the recent work of Browman and Goldstein (see e.g. Browman and Goldstein 1989), who have also proposed that the shared articulator system is projected onto separate consonant and vowel planes; in other respects, however, the two approaches are quite different (see Clements, forthcoming, for discussion). In general, there is need for further exploration of the implications of this model for concurrent research in phonetic interpretation, especially at the articulatory level.

Thus, our results point to many interesting and important questions that remain open and in need of further study.

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Notes

1 Thus, rules spreading the minus values of the vowel features in (2) also appear to be rare. See e.g. Schane (1984) and Anderson and Ewen (1987) for proposals to treat all vowel features as one-valued, and de Haas (1988), Clements (1990, 1991), and Kaze (1991) for critical discussion.

2 Other formulations are possible, and are currently under investigation. For example, following a suggestion due to Elizabeth Hume, we might assume that an automatic restructuring process applies to the output of spreading, mapping the ill-formed configuration on the left in (8) directly into the one on the right, with [labial] linked directly under the C-place node of the consonant. In this analysis, there would be no intermediate stage in which the consonant bears a secondary articulation.

3 This agreement may extend to the vowel plus labial sequences at a more abstract level of analysis. As Reighard points out, the unexpected [ë ë̆] after the labials may be explained by the fact that Maxacalí has /o/ but no /u/, motivating a redundancy rule which makes rounded vowels nonhigh. The expected high labial epenthetic vowel *[u] is thus mapped into a back rounded [o] by the redundancy rule, and then converted into the corresponding unrounded vowels [ë ë̆] by a further rule requiring all extra-short vowels to be nonlabial. The value [ə] occurring after [t, n] may simply represent the default vowel, in which case it does not give evidence for the feature analysis of the dentals.

4 As noted, Martin finds a very small number of exceptions to this general statement. However, I am told by Hyunsoon Kim (p.c.) that most of the apparent exceptions appear to involve morpheme sequences or unassimilated loanwords.

5 It is natural to ask whether this process also affected intervocalic [ð] from earlier [t d] when it occurred adjacent to a front (i.e. coronal) vowel. In fact, this segment did not undergo deletion in parallel with the other voiced fricatives, but survived to a later date when it was deleted across the board in intervocalic position: e.g., L. *vita* > *vie, nativu* > *naïf, coda* > *queue*. Thus the constraint seems to have been operative only on the (presumably more marked) features [labial] and [dorsal].

6 I have found no strengthening or weakening processes involving [pharyngeal]. This may be due to the fact no languages appear to distinguish between pharyngeal consonants and pharyngeal glides.

7 If front vowels were also assigned the feature [dorsal], as assumed in Sagey (1986), we would incorrectly predict that [y] should strengthen to velar consonants in the same way.

8 Elsewhere in Romance, velars commonly weaken to palatal glides before consonants, as in French *souiller* < Vulgar Latin *suc(u)lare* (E. and J. Bourciez 1967); this change may

have involved a structure-preserving merger of intermediate [ɰ̟] with the independently-occurring palatal [y].

9 For phonological evidence that emphasis is not simple pharyngealization but a complex secondary articulation of dorso-pharyngealization, see Herzallah 1990.

10 I assume that the glide [w] forms a single timing unit with the preceding labial, analogously to the analysis of Luganda given in Clements (1986). This assumption is not crucial to the argument, however.

11 Similar examples, differing in detail, can be cited from other Bantu languages including Kinyarwanda (Kimenyi 1979, Sagey 1986), Kirundi (Broselow and Niyondagara 1989), and Shona (Doke 1931, Maddieson 1990). Sagey argues that in Kinyarwanda and Shona, the process in question gives rise to complex segments (multiply articulated stops) rather than to CC clusters. Maddieson (1990) presents evidence that in Shona, at least, the intrusive element is sequenced, rather than simultaneous at the phonetic level. The present analysis of Venda is consistent with both views, since the resulting segment constitutes a single timing unit (C) but is internally sequenced, i.e. a contour segment in Sagey's terms.

12 The reader is referred to Ni Choisáin (1991) for much additional evidence showing that the secondary articulation features of palatalization in Irish must be located under the vocalic node or its formal equivalent.

13 Hume (1991) shows that even in languages with template morphologies, total vowel spreading can take place across consonants in post-tier-conflation representations.

14 On the other hand, we expect that consonants with phonologically specified secondary articulations will block such rules, since they have a vocalic node, as shown in Figure 1. No Kolami consonants have phonologically specified secondary articulations.

15 The same predictions hold in the model proposed by McCarthy (1991), in which laryngeals are characterized by a pharyngeal node but not by an oral (cavity) node.

16 This example was given to me by E.-D. Cook (personal communication).

17 The primary acoustic effect of dorsalization (tongue body backing) is the lowering of the second formant, while the primary acoustic effect of pharyngealization (tongue root retraction) is the raising of the first formant. Cook's measurements therefore suggest that dorsalization is a major, if not necessarily the only parameter involved in the sharp/flat distinction. This is consistent with his description of the flat sounds as similar to the emphatics of Arabic, since as will be recalled from the earlier discussion, emphasis in Arabic appears to consist of dorso-pharyngealization (Herzallah 1990). -- It should be noted here that the locus values cited above occur reversed in Cook's article (p. 128); I thank Prof. Cook for confirming that this is a typographical error.

[18] There is a typographical error in Cook (1987), giving "š" instead of the correct "ŝ" in the first underlying form.

[19] Besides accounting for the articulatory facts, this analysis gives us a straightforward account of the acoustic properties of [y:] and [ʉ:]. Fant's formant measurements show that F_2 and F_3 move in separate directions for the primary labial and palatal strictures: F_2 and F_3 fall in the [ʉ:] and [u:] glides, while F_3 (and to a lesser extent F_2) rise in the [y:] and [i:] glides. According to Fant, the rising F_3 of the [y:] diphthong owes to the fact that the narrow palatal constriction overrides the effect of the simultaneous lip rounding, while the lowering of F_2 and F_3 in the [ʉ:] diphthong is due to the fact that lip narrowing overrides the lesser constriction in the tongue palate passage (Fant 1971a, 194). In the present system, these differences follow from the different hierarchical status of [+coronal] and [+labial]: [+coronal] overrides [+labial] in [y:] where it functions as a C-place feature, but is overriden by [+labial] in [ʉ:] where it functions as a V-place feature.

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