THE REPRESENTATION OF FEATURES AND RELATIONS IN NON-LINEAR PHONOLOGY

by

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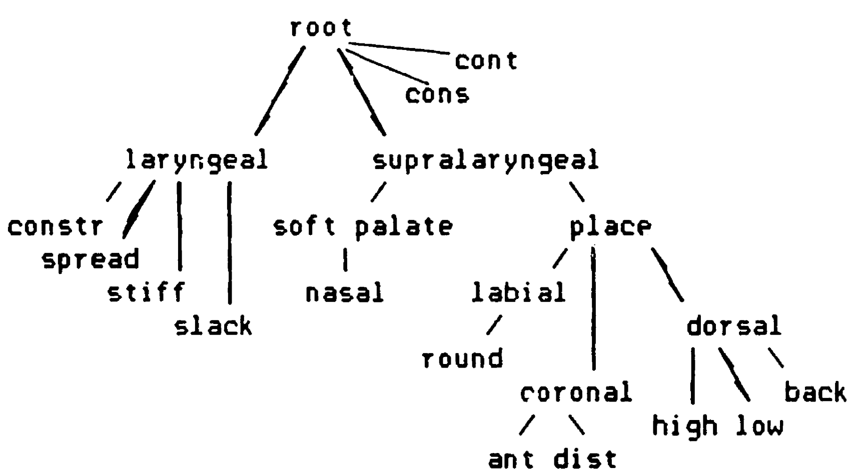
ABSTRACT

In this thesis, I propose the following hierarchical representation for the distinctive features of phonology.



This hierarchy is based on phonetics: Features are grouped according to the articulator in the vocal tract that they are executed by. Articulators are grouped according to their acoustic effects on the formant structure. The hierarchy, which is proposed to be universal, provides a straightforward explanation for the complex phenomena that surround multiply-articulated segments, such as labiovelars, labiocoronals, coronovelars (e.g. clicks), and labialized, palatalized, or velarized consonants. This type of segment, with unordered or simultaneous multiple articulations, I refer to as a complex segment. The theory of representation I propose makes it possible to represent all the complex segments that occur, and provides an explanation of why those complex segments that occur are possible in language, as well as of why those that do not occur are impossible. Furthermore, it makes possible an account of the derivation of complex segments, where they are derived, and of their behavior with respect to phonological processes. In addition, the proposed theory of representation is shown to account for unrelated phenomena in languages without complex segments, which provides independent support and shows that the representation is universal, rather than particular to complex segment languages.

In Chapters 1 and 2, I argue for the hierarchical feature groupings shown above. (The root, laryngeal, supralaryngeal, and place constituents were proposed by Mohanan (1983) and Clements (1985).) I demonstrate that the only complex segments that occur are those combining two or more of the hierarchical constituents: labial, coronal, dorsal. I argue, based on timing, syllabification, reduplication, compensatory lengthening, prenasalization, and nasal assimilation, that complex segments occupy single x-slots, and furthermore that the multiple articulations in complex segments must be represented within a single place node. Complex segments are contrasted with contour segments, in that the latter involve sequences of articulations within a single segment -- a distinction which determines the different behavior of complex and contour segments with respect to phonological rules. Furthermore, I show that the structure within the place node required by complex segments finds independent support in languages without complex segments. For example, the structure allows us to account for patterns of blocking and transparency in harmony systems. Thus, the structure within the place node is a universal property of the representation of distinctive features, rather than a just peculiarity of complex-segment languages.

In Chapter 3, I propose a mechanism for assigning the degree of closure features [continuant, consonantal] to the articulators that execute them. This representation of degree of closure features is necessary in order to account for the behaviors of complex segments, and furthermore allows degree of closure in complex segments to be represented identically to that in simple segments. The modifications of the feature representation that are necessary to represent and account for the behavior of complex segments lead to a concise characterization of the possible complex segments in human language.

In Chapter 4, I redefine the distinctive features (i.e. the terminal nodes in the hierarchy) in light of the proposals made in Chapters 1, 2, and 3, and I define the non-terminal nodes in the hierarchy.

Chapter 5 contains a further demonstration of the possibility of explaining phonology in terms of external factors. I demonstrate that the association lines among features and x-slots that connect all the tiers in the hierarchy must represent the relation of overlap in time, and I show that when they are correctly defined as representing overlap, the ill-formedness of crossing association lines follows from the relations represented in a phonological representation, together with knowledge of the world, and need not be stipulated as a well-formedness condition in UG.

Finally, in Chapter 6, I discuss two aspects of phonetic representation that are made possible by the view of phonological representations taken in Chapters 1 through 5 -- degrees of closure of individual articulators and subsegmental timing.

Thesis Supervisor: Professor Morris Halle

Title: Institute Professor

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I owe to Morris much of the central ideas in the thesis -- indeed I often can draw no clean line between his suggestions and my own. Also, both Morris and Donca examined carefully all my proposals, made suggestions for further research, and pointed out problems. I wrote every draft trying to anticipate their objections, a habit that will stick with me and improve my future work, also.

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For their kind words, for dropping by for chats, for reading and commenting on drafts (usually at the last minute), for dancing with me, arguing with me, and laughing with me, I am grateful to: Diana Archangeli, Mark Baker, Maggie Carracino, Hyon Sook Choe, Jennifer Cole, Alicja Gorecka, Ewa Higgins, Judy Kegl, Kyle Johnson, Mary Laughren, Juliette Levin, Dinette Massam, Katie McCreight, Nancy Peters, Marc Ryser, Doug Saddy, Richard Sproat, Lisa Travis, Loren Trigo, my friends at Ashdown House and Green Hall, and especially my classmates, Peggy Speas, Tova Rapoport, Myung-Yoon Kang, Naoki Fukui, Maggie Browning, and Andy Barss. I owe special thanks to Tova, who has provided immeasurable moral and professional support for four years. I can always count on Tova for encouragement or for an argument about phonology when I need it.

Robert contributed to this thesis to a degree only a phonologist could appreciate -- he programmed the word-processor to put in diacritics. I am very grateful to him for this help. Robert also originally helped me to realize six years ago how interested I was in linguistics -- by telling me how much I talked to him about it -- and he continued to listen as my conversation became increasingly confined to one topic during the writing of this thesis. For all of his help, his understanding, and for all he was willing to give up for my pursuit of this degree, I thank him.

Table of Contents

Chapter 1

INTRODUCTION

Fundamental to every theory of phonology is how phonological forms and processes are represented within it. It should be possible to represent within the theory any phonological process or form that is possible in human language, and it should be impossible to represent phonological forms and processes that do not exist in human language. For example, one type of form that occurs in language is a sequence of tones within a single segment -- i.e. a contour tone. Thus, autosegmental phonology is an improvement over segmental phonology because it allows the representation of such sequences of tones (see Goldsmith (1976)). Conversely, because doubly-articulated palatal and velar stops do not occur in language, a theory in which it is impossible to represent a doubly-articulated palatal and velar stop is more highly valued than a theory in which such a segment can be represented. For the same reason, autosegmental spreading is a better representation of the process of assimilation than is changing values in a feature matrix because it makes it impossible to represent assimilations in which the target takes on a feature which is not present in the trigger, a type of assimilation which doesn't occur.

Another requirement on the theory is that the relative simplicity of describing in the representation each process or form that occurs should reflect its relative naturalness, in the sense of its frequency of occurrence in the languages of the world. That is, more marked forms and processes should correlate with more marked representations. For example, the assimilation of a whole group of features (e.g. place features) is just as natural in language as is the assimilation of a single feature. This naturalness is captured by the representation of assimilation as autosegmental spreading, along with a hierarchical feature representation, which together have the result that the assimilation of a group of features is represented just as simply as is the assimilation of a single feature. This naturalness is not captured by the representation of assimilation as changing individual features in a feature matrix, in which the two types of assimilation are not equally simple.

Finally, the structure of the phonological representation is an hypothesis about the structure of linguistic knowledge in the human brain. Not all descriptively adequate representations are equal. Rather, in addition to describing the phonological array of facts, the representation should lead to explanations, where possible, of why the facts are as they are, and of why the representation is structured as it is. Therefore, to the degree that the properties of a representation can be explained based on such factors as vocal tract anatomy, acoustics, or knowledge of the world, that representation is more highly valued than another representation which accounts for the same phonological facts but in an arbitrary fashion. Of course, this is not to say that all phonological phenomena will be reduceable to explanation in terms of such factors, but rather that any phenomena that are so reduceable should be characterized as such by the phonological theory. The theory should not attribute to arbitrary aspects of the phonology what is explainable on the basis of phonetics or knowledge of the world. For example, it was mentioned above that the representation should reflect the fact that doubly-articulated palatal and velar stops do not occur. A descriptively adequate theory that correctly rules out such segments, but which does so in an arbitrary way, is less highly valued than a theory which recognizes that the impossibility of palatal-velar doubly-articulated segments is simply a result of palatals and velars being formed with the same articulator in the mouth, i.e. the tongue body, which obviously cannot be in two places ([-back] and [+back]) at the same time.

The above requirements -- that a theory represent all and only the forms that occur in language, that it reflect the relative markednesses of those forms and processes in their representation, and that it account for the forms and processes that occur in a non-arbitrary manner -- have been notoriously difficult to achieve with respect to segments with multiple simultaneous articulations, for example labiovelars, clicks, and labialized or palatalized consonants. Such segments have long posed problems for phonological analysis, both for their representation and for the processes deriving them. This is especially true within such non-autosegmental frameworks as Trubetzkoy (1958), Jakobson, Fant and Halle (1952), and Chomsky and Halle (1968), in which segments are characterized as unstructured, homogenous, feature matrices. Such representations require that every segment have only one primary articulation, so that one of the articulations in a labiovelar or a corono-velar click has to be treated as secondary, and must be represented by vowel features. For example, /kp/ can be represented either as a [+round] velar or as a [+back] labial, but not as both labial and velar. Furthermore, for a corono-velar, there is not even a choice in these earlier frameworks as to which articulation is primary. A corono-velar can be represented only as a [+back] coronal, i.e. with primary coronal articulation. However, as I show in Chapter 3, labiovelars in Nupe must be analyzed as having two primary articulations -- labial and velar -- and corono-velar clicks in !XŨ must must be analyzed as having primary velar articulation, with secondary coronal articulation. Both the labiovelars in Nupe and the corono-velars in !XŨ are impossible to represent within the non-autosegmental theories. The problem with the feature matrix representation is that it doesn't allow the straightforward representation of two equal articulations within a single segment, nor even always of the proper articulation as primary.

Non-linear phonology,[1] on the other hand, does allow the representation of two equal articulations within a segment. Non-linear phonology has provided an excellent representation for non-steady-state segments such as affricates, prenasalized stops, and vowels with contour tones, because unlike the feature-matrix representation, it allows sequences of articulations within a single segment, represented by many-to-one mappings such as those in (1).

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1. See references in footnote 3 below.

```
(1)   affricate:        prenasalized stop:     contour tone:

         t   s               n   d                 H   L
          \ /                 \ /                   \ /
           x                   x                     x
```

Thus, the framework of non-linear phonology might be expected to handle easily all segments with more than one articulation. However, representations of the type in (1), in which the two articulations are in sequence, are not adequate for segments with multiple simultaneous articulations (which I will call complex segments), precisely because the articulations in such segments are not phonologically in sequence. Non-linear phonology has so far provided a representation for multiple sequential articulations within a single segment, as in (1), but not for multiple simultaneous or unordered articulations within a single segment, as exist in complex segments such as Igbo [kp], Margi [pt], Kinyarwanda [tkw], and !Xũ [!] (corono-velar click).

Thus, non-linear phonology, in its current state, fails as a representation in that it cannot account for the possible complex segments in human language. In this thesis, I propose a theory of phonological representation that is an improvement over previous theories of representation. Not only does the theory I propose provide a representation for all and only the complex segments that occur in language, but it also accounts for the phenomena surrounding complex segments -- i.e. their derivation and their behavior in phonological processes -- and it accounts for them in a non-arbitrary manner, relating them to aspects of vocal tract anatomy.

The universal representation of distinctive features I argue for in

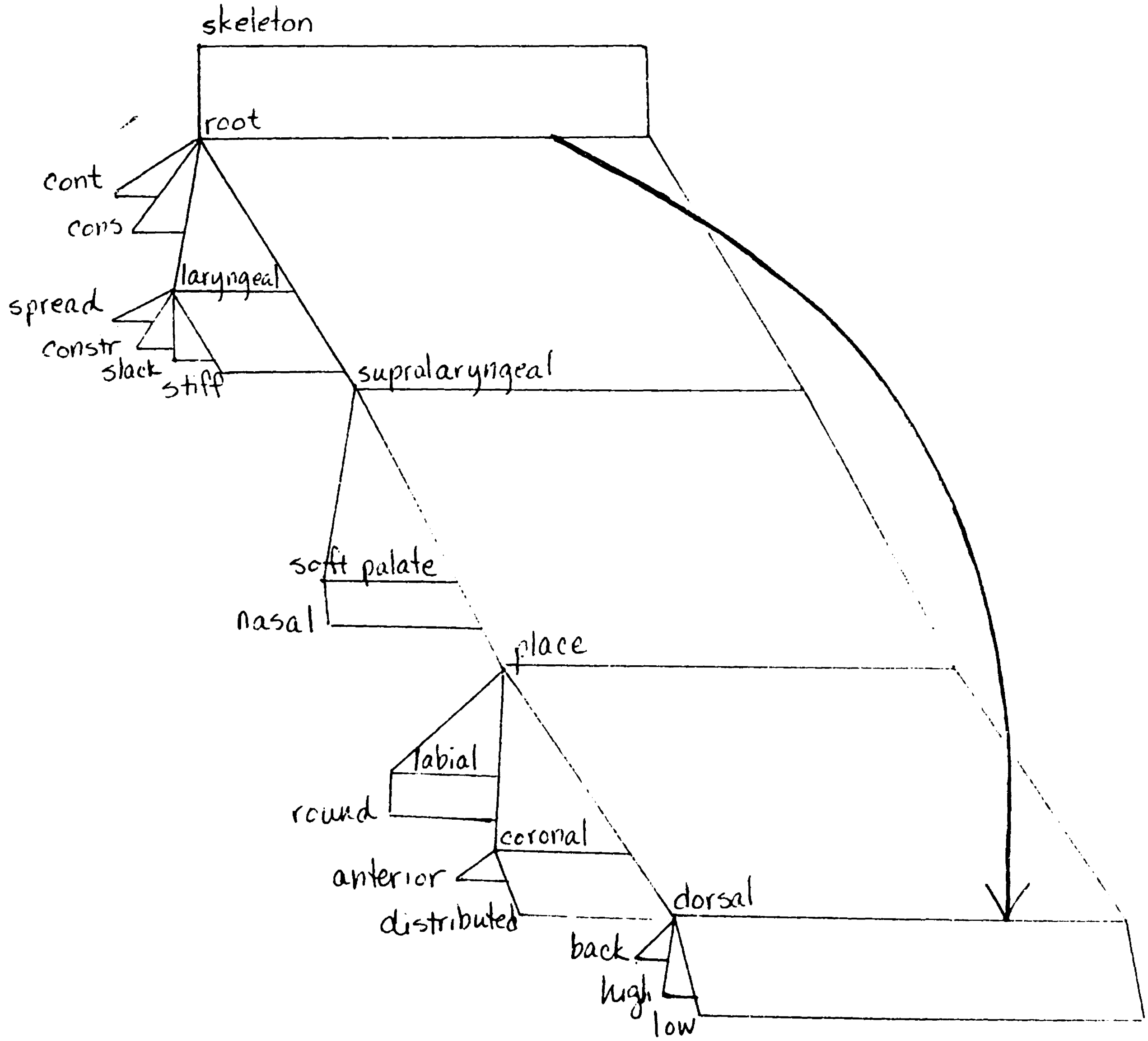

skeleton
root
cont
cons
laryngeal
spread
constr
slack
stiff
supralaryngeal
soft palate
nasal
place
labial
round
coronal
anterior
distributed
dorsal
back
high
low

Figure 1

this thesis is that in Figure 1. Figure 1 is a hierarchy which reflects various dependencies and independencies among the distinctive features, as well as their groupings into constituents. At the lowest level are the individual features, such as [continuant], [round], [high], etc. These I will call terminal nodes, or terminal features, following Clements' (1985) terminology.

Most of the terminal features are grouped at the next level in the tree into constituents according to which articulator in the vocal tract executes the particular feature. For example, [high], [back], and [low] are all grouped under the dorsal constituent, because they are executed by the dorsum, or tongue body. The lowest level of non-terminal nodes in the tree thus represent articulators: laryngeal, soft palate, labial, coronal, and dorsal.

These articulators are further grouped into higher-level constituents. Labial, coronal, and dorsal are grouped into a place of articulation constituent. The place node and the soft palate node are then grouped into a supralaryngeal constituent. The place and supralaryngeal constituents do not correspond to articulators, but rather reflect the different acoustic effects of the features they govern. Supralaryngeal features affect the shape of the formant structure, while laryngeal features do not. Among the supralaryngeal features, place features affect the shape of the formants to a greater degree and in a qualitatively different manner than do nasal features. Place features change the formants by changing the shape of the resonator; nasal features by adding a second resonator.

Finally, the laryngeal and supralaryngeal features are grouped into the root constituent. The root constituent corresponds neither to anatomy of the vocal tract nor to acoustic properties. Unlike the other non-terminal nodes in the hierarchy, which are both phonetically and phonologically motivated, the root node is solely a phonologically motivated constituent.

The root, laryngeal, supralaryngeal, and place nodes in the hierarchy have been proposed by Mohanan (1983) and Clements (1985). The labial, coronal, dorsal, and soft palate nodes were proposed in Sagey (1984).

[Continuant] and [consonantal] do not occur under any articulator constituent in Figure 1 because they are not executed by any particular articulator, but rather may be executed by either the labial, the coronal, the dorsal, or even, I will argue, the laryngeal articulators. Thus, they are represented as attaching directly to the root node. The arrow in Figure 1 represents a relation that may exist between the root node and any articulator node. This relation determines which articulator the degree of closure features [continuant, consonantal] apply to.

All of these aspects of the structure in Figure 1 will be argued for in this thesis. I will show that the structure in Figure 1 allows us to account naturally for some quite complex phenomena that occur in languages with multiply-articulated segments. Furthermore, I will argue that the feature hierarchy is independently supported by processes in languages without multiply-articulated segments, and thus that it is a universal representation, not just a representation for languages that have multiply-articulated segments. Finally, the representation of features I propose is grounded in facts of vocal tract anatomy and acoustics. Humans produce speech using specific articulators in the vocal tract, which produce characteristic effects on the acoustic waveform; the waveform is then perceived and processed by the human auditory system. It would be surprising if this physical mechanism of speech did not influence the structures, representations, processes, and segment inventories found in phonology.

All theories, of course, acknowledge to some degree the influence on phonology of anatomy and acoustics. For example, most would accept that the reason for the impossibility of [-back,-high] stops is anatomical, it being physically impossible to form a closure with the tongue when it is in that position, as pointed out by Halle (1982). Similarly, it is recognized that the impossibility of [+high, +low] segments follows from the fact that [+high] and [+low] require the tongue body to be in two incompatible positions -- raised and lowered. However, I propose that much more of phonology is due to the physical mechanism of speech than is sometimes assumed. Greater understanding of phonology, and a more explanatory phonological theory, result from investigating phonology hand in hand with phonetics. In phonetics are often found explanations for why phonology is the way it is. For example, "place of articulation" is a basic, and long-recognized, parameter in phonology. Features dealing with place of articulation form a natural class of features. Is it an accident that those features we refer to as place of articulation features form a class in phonology? Could human language just as easily have grouped the features [constricted glottis], [coronal], and [low] into some parameter? This would be expected if the grouping into place features were purely formal, and not grounded in some way in the physical mechanism of speech. However, the grouping of features into a place constituent is not an accident, but is due to the physical mechanism of speech. Place features are those features that cause the type of changes in formant structure resulting from changes in the shape of the resonator, as opposed to nasality, which changes the formants by adding a second resonator, or as opposed to laryngeal features, which don't change the formant shapes at all. Thus, phonetics can explain why there is a unit "place of articulation" in phonology.

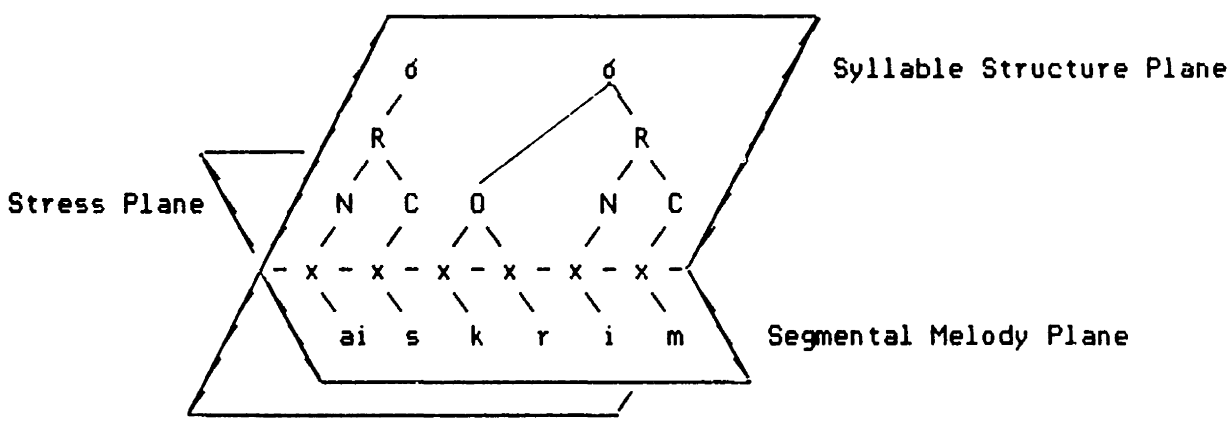
In addition to the aspects of phonology that are explainable in terms of phonetics, there are aspects of phonology that may be explained based on the speaker's knowledge of the world. I argue in Chapter 4 that the Well-Formedness Condition which disallows crossing association lines is one such aspect of the phonology. It need not be stated in any form as a principle of UG (i.e. an arbitrary, unexplained, aspect of language), because it derives from the fact that the segments making up a word are in relations of precedence in time, the properties of which are included in the speaker's knowledge of the world.

In short, I maintain that by taking phonetics and knowledge of the world into account, much more can be explained about phonology than is sometimes assumed, and thus that much less needs to be attributed to arbitrary properties of the phonology.

1.1 Non-Linear Representation

I assume in this thesis a version of non-linear phonology. I take as point of departure a phonological representation as in (2).[2] (2) is a three-dimensional structure consisting of a number of half-planes, all of which intersect in a central line made up of a sequence of timing units, or x-slots. Some of the half-planes in a non-linear representation are the syllable structure plane, the stress plane, and the segmental melody plane, as illustrated in (2) with a partial representation of the word 'ice cream'.

(2)



The representation in (2) assumes certain notational conventions. First, left-to-right order on a single line represents <u>precedence in time</u>.

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2. Arguments for various aspects of the representation in (2) may be found in: Williams (1971); Goldsmith (1976,1981); Mascaro (1982); Steriade (1982;1983); Halle and Vergnaud (1980); Levin (1985). I will not reiterate those arguments here.

For example, the x-slots in (2) form an ordered sequence, in which x_1 precedes x_2, x_2 precedes x_3, and so on.

Second, only elements on a single line are related by precedence. Thus, the multiple lines of representation in a three-dimensional structure like (2) represent elements that are unordered with respect to each other. For example, the melodic features represented by the letters "ai,s,k,r,i,m" on the segmental melody plane are not ordered with respect to the x-slots.

Third, the structure on the syllable plane encodes dominance: the syllable node dominates the onset and the rime; the rime dominates the nucleus and the coda; and the onset, nucleus, and coda dominate x-slots. These dominance relations are represented by the lines in the tree, e.g. the line linking the rime to the nucleus represets that the rime dominates the nucleus.[3] Structure on the stress plane also encodes dominance.

Finally, the lines on the segmental melody plane linking the features to the x-slots are association lines. Association lines represent the relation of overlap in time.[4] Only elements that have internal duration are capable of overlapping in time. Thus, if association lines represent overlap, as I argue in Chapter 5 that thry must, then the elements that

----

3. I use the constituents onset, rime, etc., to illustrate dominance on the syllable plane. Nothing hinges on the choice between the type of syllable structure in (2) and the type argued for by, e.g., Anderson (19__), Levin (1985), in which the only syllabic constituents are projections of the nucleus.

4. Association lines have been generally assumed to represent simultaneity. However, I demonstrate in Chapter 5 that assuming them to represent simultaneity leads to contradictions of precedence relations in contour segments and geminates.

they link -- x-slots and features -- must have internal duration. I will therefore assume that both x-slots and features have internal duration, although that duration is inaccessible at the level of phonological representation. This has been already assumed for x-slots, since they encode timing, or duration. While features do not explicitly encode duration, however, it is nevertheless natural to assign them internal duration, for the articulations they specify cannot be produced instantaneously, but will always occupy some amount of time, or duration. These issues are discussed further in Chapters 5 and 6.

Phonological representations may not contain association lines linking features to x-slots as in (3), where [a F] precedes [b F] and x_1 precedes x_2:

(3) * [a F] [b F]

x_1 x_2

I demonstrate in Chapter 5 that the ill-formedness of (3), in which the association lines cross, is due to its encoding contradictory precedence statements. It need not be stated as a well-formedness condition in UG.

An advantage of the representation of features and x-slots in (2) over the earlier feature matrix approach (as, for example, in SPE), is that it allows many-to-one and one-to-many relations between features and x-slots, representing, respectively, contour segments and geminates, as in (4):

(4)

```
a.  Contour                                              b.   Geminate

    Affricate       Prenasalized         Tone              Segment       Tone

 [-cont][+cont]   [+nasal][-nasal]       H   L                F            H
      \ /               \ /               \ /                / \          / \
       x                 x                 x                x   x        x   x
```

A contour segment is represented as in (1a) to capture the fact that although it is made up of a sequence of articuations and behaves phonologically as a sequence of features, it also behaves phonologically as a single segment. Conversely,a geminate is represented as in (4b) to capture the fact that although it consists of a single articulation and behaves phonologically as a single feature specification, it also behaves phonologically as two segments. Thus, the representations in (4) solve long-standing paradoxes as to whether affricates and geminates constitute single segments or sequences of two segments.

Another advantage of one-to-many linkings between features and x-slots is that it makes possible a characterization of natural assimilation rules as rules which spread (by adding an association line) a feature specification onto a neighboring segment.[5] Under this mechanism of assimilation, rather than feature values being changed in the matrix of the segment undergoing assimilation as in (5a), the feature specification of the triggering segment is spread onto the target by adding an association line between the features of the trigger and the x-slot of the target, as in (5b).

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5. Spreading assimilation has been argued for by, among others, Halle and Vergnaud (1980), Goldsmith (1981), Steriade (1982), and McCarthy (1984).

(5) a. Feature Value Changing Assimilation

$$\begin{bmatrix}+F\\-G\end{bmatrix} \quad \begin{bmatrix}-F\\+G\end{bmatrix} \quad ==> \quad \begin{bmatrix}-F\\+G\end{bmatrix} \quad \begin{bmatrix}-F\\+G\end{bmatrix}$$

b. Spreading Assimilation

(5b) captures the fact that in assimilation, a segment changes to become identical to some segment in its environment with respect to certain features; that is, the features of the trigger are simply realized on the target. There is no way for a feature not in the environment to end up on the target in a spreading assimilation. In contrast, feature value changing assimilations can, in principle, change neighboring segments to opposite values of the context feature, or change the value in an unrelated feature, or even affect segments not in the immediate environment. Such processes are extremely uncommon in comparison to assimilations where the target takes on some feature in the environment. Thus, spreading is a more explanatory mechanism for assimilation than is changing feature values, because it reflects the difference between natural assimilations and the more uncommon processes that can only be described by changing feature values.

An interesting class of evidence exists that supports the autosegmental representation of assimilation as creating a linked structure, as in (5b). This evidence concerns the "inalterability" of linked structures, meaning that they are often not subject to rules which should otherwise apply to them. For example, spirantization in Tiberian

Hebrew normally applies to post-vocalic stops, but fails to apply to a post-vocalic stop that forms the first half of a geminate, or linked, structure, as shown in (6).

```
(6)     s i b  e b              s i b  e B
        | | |\ | |              | | |\ | |           [sibbeB]  "he surrounded"
        x x x x x x     ==>     x x x x x x          (*[siBbeB])
```

One explanation of inalterability with regard to feature-changing rules and deletion rules is that of Hayes (1984), which states that association lines in phonological rules are interpreted as exhaustive and that structures having more association lines than the rule do not meet the structural description of the rule. Linked structures are also impervious to epenthesis. This follows, as was noted by Kaye (cited in Steriade (1982)), from the impossibility of specifying the features of the epenthesized segment without crossing the association lines of the linked structure.[6]

Although autosegmental representations solve the problem of representing geminates and affricates, and even lead to the more explanatory, because more restricted, mechanism of spreading assimilation, there is still a major problem that autosegmentalizing features and spreading assimilation do not solve. It has long been noted (see, e.g. Thráinsson (1978), Goldsmith (1981), Mohanan (1983), Steriade (1982), and Mascaro (1983,forthcoming)) that certain groups of features tend to recur in phonological rules, for example, the set [ant, cor, high, back] defining place of articulation. However, the evaluation metric predicts that a rule

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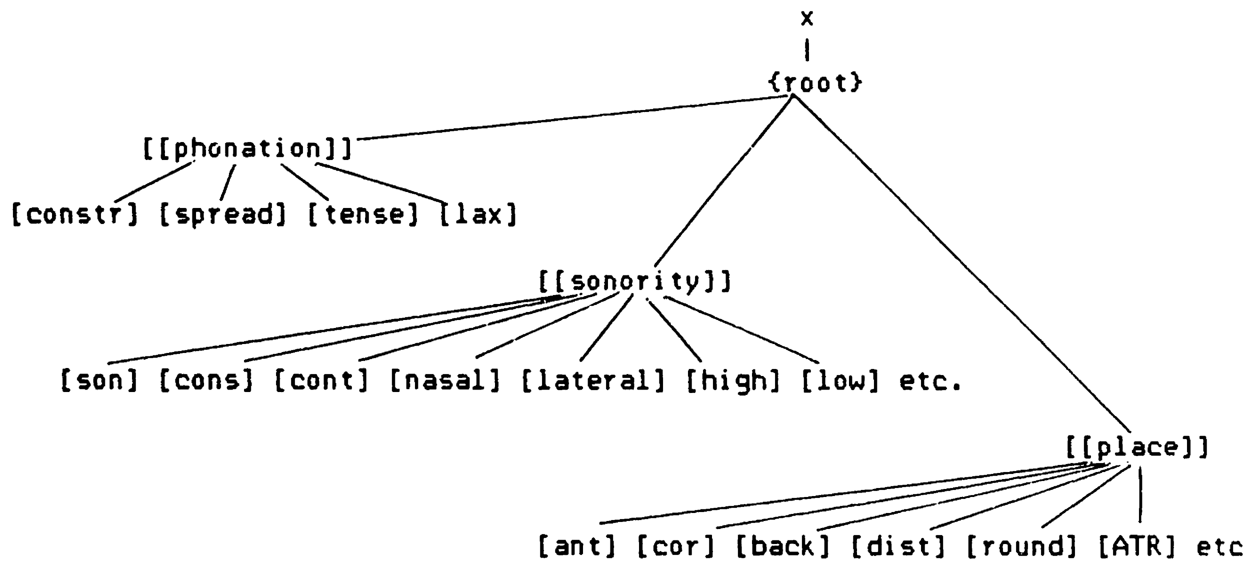
6. Nothing in my argument hinges on the particular explanation of inalterability assumed. See also Steriade and Schein (to appear) for a different account of inalterability.

spreading all of these should be less highly valued than a rule spreading some subset of them. The problem is how to characterize that it's more common or natural to spread the whole set of features rather than just a few of them.

1.2 Feature Groupings

To solve this problem, it has been proposed that distinctive features be represented, not as a feature matrix in which all the features have the same status and are equally interrelated (or not), but rather grouped according to parameters such as "place" and "manner" which tend to recur in phonological rules. That is, just as the sets of <u>segments</u> that occur together in phonological processes can be characterized as phonetically natural classes, so also the sets of <u>features</u> that occur together phonologically may be phonetically defined as "natural classes" of features. Neither the features defining natural classes of segments nor the "features" defining natural classes of features are arbitrary. Both reflect phonetic groupings. Mohanan (1983), for instance, proposes a universal hierarchy of features to represent the functional groupings: place of articulation, sonority, and phonation.

(7) Mohanan (1983)



Throughout this discussion an assumption has been that segmental melody features are arranged on a two-dimensional half-plane, the segmental melody plane in (2). This assumption is made explicitly in Archangeli (1984), who states that "planes intersect only at the skeleton". However, there is no a priori reason for assuming that the segmental melody is restricted to a two-dimensional representation. In fact, assuming a three-dimensional representation for segmental melody features enables us to represent the feature groupings in (7) as part of the geometry of the phonological representation (as opposed to representing the feature groupings non-structurally, i.e. marking all the features under the place node in (7) as "place features" as part of their definition and allowing subclasses of features to be picked out by rules on the basis of the content of their definitions).

Clements (1985) makes explicit the three-dimensionality of the representation of segmental melody features with the representation in Figure 2 -- a universal, non-linear, hierarchical representation for

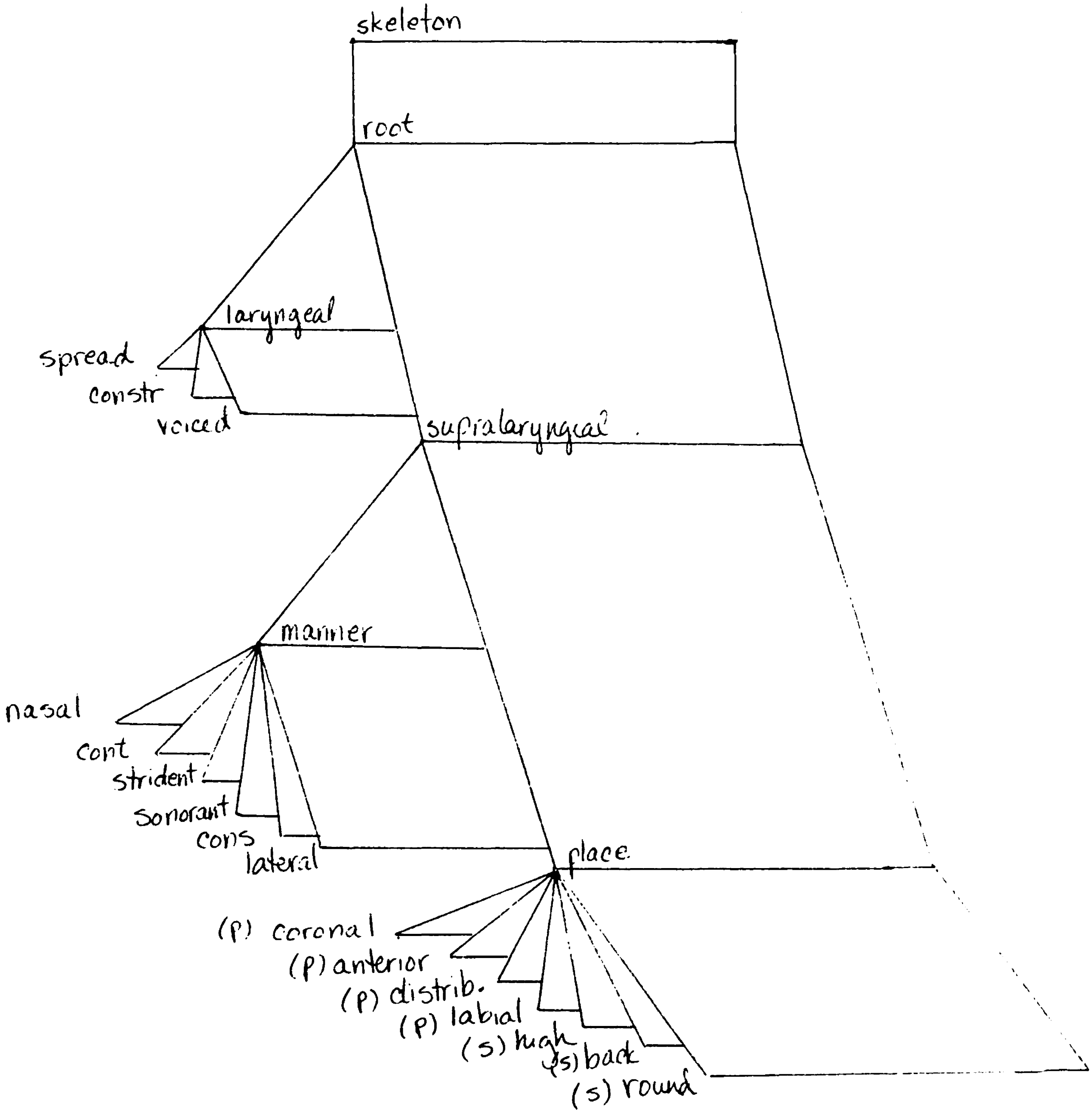


Figure 2 (Clements (1985))

distinctive features.[7]

Given a three-dimensional structure as in Figure 2, we must distinguish two types of multiple linkings. First, there are the branchings to different specifications on a single tier, as in contour segments, in which the two specifications are phonologically ordered.

```
(8)              manner
                  /   \
            [-cont] [+cont]
```

Second, there are branchings to elements on different tiers. Since the elements in such linkings are on different lines of representation, they are unordered, as in the branching to laryngeal and supralaryngeal in (9).

```
(9)             root
                 / \
           laryng. supralar.
```

It is often necessary to represent both types of branchings at once, but keep in mind that it is only branchings to specifications on a single tier that are phonologically ordered.

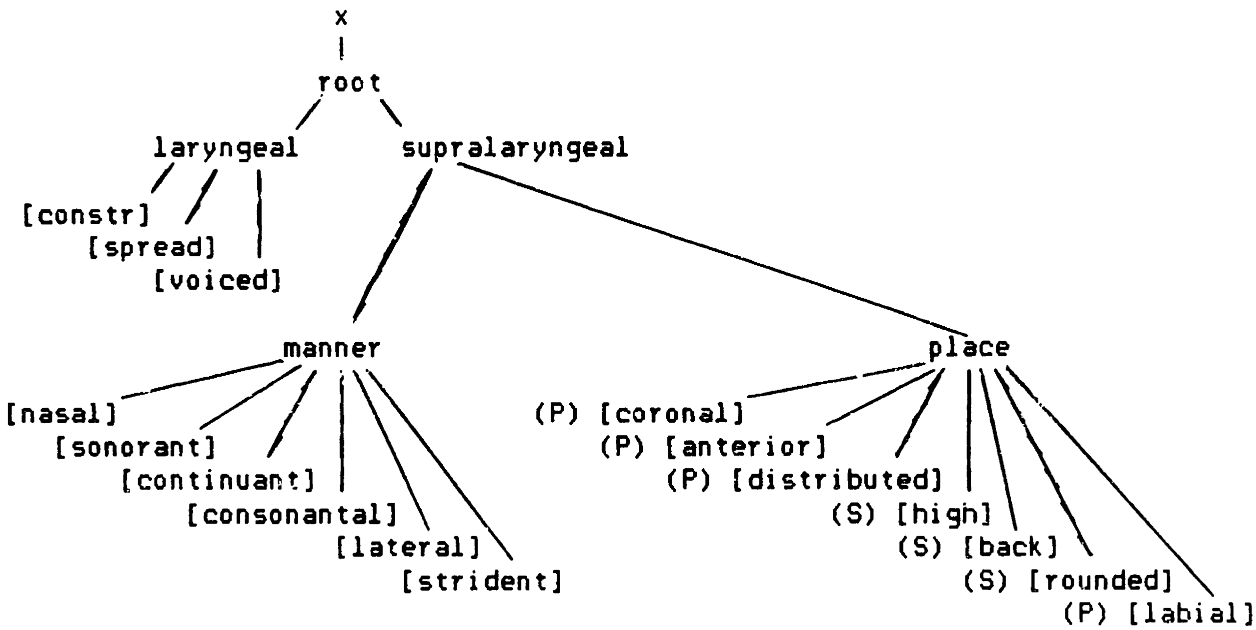
Henceforth, to make easier its depiction on a two-dimensional page, I will represent the feature hierarchy, not three-dimensionally as in Figures 1 and 2, but two-dimensionally, from the perspective of looking down the axis of the skeletal core, what I shall refer to as the 'end view'. Viewed from the end, Clements' hierarchy in Figure 2 would appear as in (10).

----

7. (P) and (S) distinguish primary and secondary place of articulation features. A different characterization of the distinction between these features is proposed in chapter 2.

1.2 Feature Groupings

(10) Clements (1985): End View



That is, imagine that the skeletal tier, the class tiers, and all the feature tiers are perpendicular to this sheet of paper and parallel to each other. Viewed from the end, as in (10) or in (11), the branching of a contour segment will not be visible:

(i) Contour Segment: a. Regular, Front View b. End View

Consider now the various constituents in the hierarchies proposed by Clements and Mohanan. Clements' hierarchy is explicitly meant to reflect only those groupings or relationships among features that are justified by phonological processes, and none that are justified only on articulatory or acoustic grounds.[8] Following Mohanan (1983), he proposes that the

----

8. Clements argues against an articulatory explanation of the relative independence of features, and for the "autonomy of phonology", by which "the ultimate justification for a model of phonological features must be

following type of constituency be considered evidence for the feature geometry.

> If we find that certain sets of features consistently behave as a unit with respect to certain types of rules of assimilation or resequencing, we have good reason to suppose that they constitute a unit in phonological representation, independently of the operation of the rules themselves (p. 2).

Thus, rules affecting, e.g., place of articulation can refer to the unit "place of articulation features", rather than each rule that affects place of articulation having to list all the features for place of articulation.

Mohanan (1982) and Clements (1986) propose that the constitutents in the feature hierarchy may be spread, delinked, etc. by phonological rules. Thus, there should exist three equally-valued types of spreading: "_total_ assimilation processes in which the spreading element A is a root node, _partial_ assimilation processes in which A is a class node, and _single-feature_ assimilation processes in which A is a single feature. More complex types of assimilation, in which more than one node spreads at once, can be described by this model, but at greater cost" (Clements 1985:7).[9]

----

drawn from the study of phonological and phonetic processes, and not from _a priori_ considerations of vocal tract anatomy or the like" (1985:6).

9. Thus, while phonological rules may exist which spread two separate constituents, such rules will be evaluated as twice as costly as a rule spreading a single constituent, and hence grammars will tend to eliminate them. On counterexamples to the constituent-spreading hypothesis, Clements argues: "It is unlikely that all palatalisation rules will be susceptible to such an analysis. The endpoint of rule interaction is rule telescoping, by which two or more originally independent rules become synchronically indissociable. Such rules are typically lexicalised and/or grammaticalised, and may show other irregularities. ... We will not relax the empirical claims of our theory in order to provide simple descriptions of rules such as these, since if we did so we would fail to draw a correct distinction between the common, widely recurrent process types that we take as providing the primary data for our theory, and the sort of idiosyncratic

1.2 Feature Groupings

Representing assimilation as a spreading of the assimilated features, plus allowing spreading of constituents larger than single features, provides a characterization of the fact that natural, or common, assimilations always involve a segment taking on a feature or a well-defined set of features from some other segment in the environment. Assimilations in which the target takes on a well-defined set of features are, on this view, just as simple, and therefore just as highly valued, as assimilations of only one feature.

To summarize, if we assume that in general only constituents spread or delink, then evidence from phonological rules on what features need to spread together will tell us what the constituents are. That is, which features tend to function as blocks in rules is evidence for feature constituency. In the following subsections I present arguments for four of the class node constituents in Clements' hierarchy in (10) -- the root, laryngeal, supralaryngeal, and place nodes. As Clements suggests, there is no motivation for the manner features constituent. A different representation for manner features in the hierarchy will be proposed in Chapter Three.

1.2.1 Laryngeal and Supralaryngeal Nodes

The first major subdivision of the features is into laryngeal and supralaryngeal groups. This division is supported by processes which affect either only the laryngeal features or all but the laryngeal features

----

phenomena whose explanation is best left to the domain of historical linguistics" (Clements 1985:22).

(i.e. the supralaryngeal features). First, the reduction of full consonants to [?] and [h] throughout the history of English (as discussed by Lass (1976), cited in Clements (1985)) is simply a delinking of all supralaryngeal features.

(11)
```
          root
          /  \
    laryng.   ≠
             supralar.
```

The complementary case, where all laryngeal features are delinked, is attested in the neutralization of laryngeal contrasts in certain environments in Thai and Klamath, also cited by Clements:

> In Thai ... voiced stops, voiceless aspirated stops and voiceless unaspirated stops contrast in syllable-initial position; this contrast is suppressed finally, where only unreleased voiceless stops appear .... In Klamath, a three-way contrast among voiced, voiceless and glottalised obstruents is neutralised immediately preceding another stop, leading in this case to morpheme alternations ... (1985:235).

In both of these processes, the consonants lose their distinctive laryngeal features, which is represented as in (12), a delinking of the laryngeal node.

(12)
```
          root
          ≠  \
        /   supralar.
    laryng.
```

Not only delinkings, but also spreadings, provide evidence for the laryngeal and supralaryngeal nodes. In Icelandic preaspiration (as discussed by Thráinsson (1978), Clements (1985)) a geminate aspirated stop diphthongizes into a sequence of /h/ and an unaspirated stop. In other words, its laryngeal and supralaryngeal features are split, the laryngeal features spreading to the x-slot on the left, from which the original root node is delinked, and the supralaryngeal features alone remaining in the second segment.

(13)

```
      x   x                    x   x                  x    x
       \ /                      ≠  |                  |    |
       root         ==>         root        ==>     root  root
       / \                    ↖≠   |                 |     |
 laryng.  \               laryng.  |             laryng.   |
        supralar.              supralar.                supralar.
```

Note that in (13), the laryngeal node which is spread to the left does not link directly to the x-slot. Rather, a root node is "interpolated" as part of the linking process. A class node such as laryngeal, supralaryngeal, or place (or for that matter an individual feature) cannot link directly to the skeleton, because that would render the claims of the feature hierarchy vacuous. More generally, no feature or class node may link except to the nodes which are adjacent to it in the hierarchy. If ever features or class nodes were allowed to link outside of the hierarchy, as in the linking of [coronal] directly to the root node in (14),

(14)

```
              root
              /  \
     [coronal]    \
               supralaryngeal
                     \
                    place
                      |
                 [anterior]
```

then the constituency of the hierarchy would be destroyed. In (14), spreading the place node would fail to spread the place feature coronal. Thus, features and class nodes may link only through the paths of the hierarchy, and never outside it. This means that if ever a feature is spread to a segment lacking the node to which that feature must link, then that node will be "interpolated" as part of the spreading. This should not be looked at as adding a node to the representation. Rather, the hierarchy is simply part of the geometrical representation of the features, and it defines the paths through which features may link to the skeleton. Thus, it would be more proper to say that the laryngeal node in Icelandic preaspiration links to the skeleton through the root tier, rather than saying a root node is added to the representation.

Complementary to the spreading of laryngeal features in Icelandic, there exist cases of spreading supralaryngeal features. In Acoma, for example, when separated only by glottal stop, two vowels are normally identical (Miller (1965:11,79)), for example, ya?aana 'skunk brush', huu?uuka 'dove' etc. Since /?/ lacks supralaryngeal features, being specified as only [+constr gl.] on the laryngeal tier, this distribution of vowels is easily stated in terms of the vowels sharing supralaryngeal features, as in (15).

```
(15)            (a)     (?)     (a)

                root    root    root
                / \      |      / \
         laryng.   \ laryng.   /   laryng.
                    \         /
                     \       /
                   supralaryng.
```

The sharing of supralaryngeal features in (15) is possible because /?/ has no supralaryngeal node to block spreading of the vowel's supralaryngeal node.

Further evidence for the laryngeal node as an independent, unordered node with respect to supralaryngeal features is found in the behavior of prenasalized voiceless stops in Kinyarwanda. Voiceless stops in Kinyarwanda are aspirated. When a voiceless stop is prenasalized, what surfaces is a voiceless or aspirated nasal with the place of articulation of the original stop. There may also be a brief oral stop between the nasal portion and the aspiration.[10]

(16)	/in-papuro/	[imhapuro]	"paper"
	/n-toora/	[nhoora]	"vote for me", "I vote"
	/in-ka/	[iŋha]	"cow"

Since we represent the aspiration of the oral stops on an independent, unordered tier (the laryngeal tier), this realization of the aspiration of the oral stop on the added nasal portion is predicted, given that prenazalization is a merging of [+nasal] into the root node of the stop, resulting in the structure in (17):

(17)
```
                root
               /  \
          laryng.  \
            /       supra
     [+spread]      /   \
               soft-pal  place
                 /  \
          [+nasal][-nasal]
```

Furthermore, in prenasalized, labiovelarized, voiceless stops, as in (18),

(18) /ku-n-tuara/ [kuunŋwhaara] "to take me"

the voicelessness and aspiration of the stop are spread over the entire segment. This is predicted by aspiration being represented as [+spread

----

10. See Appendix A at the end of this chapter for notational conventions, such as [ŋ] in (16) for a velar nasal.

glottis] on the independent, unordered laryngeal tier.

Thus, both delinking and spreading processes in phonology support the existence of laryngeal and supralaryngeal constituents in the feature hierarchy. This division has phonetic motivation, too. First of all, the laryngeal node corresponds to an independent articulator in the vocal tract. The grouping of features executed by the larynx into a single phonological constituent is thus motivated by the anatomy of the vocal tract. There is no articulator corresponding to the supralaryngeal constituent, of course. Rather, the supralaryngeal constituent is motivated by acoustics. In contrast to laryngeal articulations, which do not change the shape of . formants, supralaryngeal articulations change the formants by changing the shape of the oral resonator or by adding a second resonator -- the nasal passage. Thus, the division between supralaryngeal and laryngeal is an acoustic division between features which distort formant structure and those which do not.[11]

----

11. Ohala (1974:259-261)) states that the articulation of spreading the glottis for /h/ causes a lowering of contiguous vowel formants because it essentially changes the resonator from a tube that is closed at one end (the glottis) to one that is open at both ends. The effect of laryngeal articulations on the shape of formants deserves further investigation. In light of the hypothesis above, I would expect to find that the distortions produced by /h/ are much smaller than those produced by supralaryngeal articulations, or that they are qualitatively different. Morris Halle (p.c) suggests that another explanation for the supralaryngeal con ent may be that it corresponds to a single pathway at some point in the neural circuitry governing speech production, but until more is known about this neural circuitry, such an explanation must remain conjecture.

1.2.2 Place Node

Under the supralaryngeal node in the hierarchy is the place node, uniting all place of articulation features. Abundant phonological evidence exists for the constituent of place of articulation features. One of the most common phonological processes in language, and one which exists in practically every language, is assimilation in place of articulation, especially of nasals to following stops. A few examples will suffice to establish the place node constituent.

First, in Kpelle, nasals assimilate in place of articulation to a following stop or fricative, as shown in (19) (Data from Welmers (1973:65,67)):

(19)	/N-polu/	[ḿbolu]	'my back'
	/N-tia/	[ńdia]	'my taboo'
	/N-kOO/	[ŋ́gOO]	'my foot'
	/N-kpiŋ/	[ḿŋgbiŋ]	'myself'
	/N-fela/	[ḿvela]	'my wages'
	/N-sua/	[ńʒua]	'my nose'

Three aspects of the data in (19) require the spreading of a place constituent. First, the nasal assimilates in place regardless of what the following segment's place features are. Thus, the process in (19) cannot be any more specific than spreading the place node. That is, it cannot be a rule spreading the feature [coronal], or [labial], etc. Second, only place features, and not manner or laryngeal features, are spread onto the nasal. /f/ conditions a labial nasal stop, not a labial nasal fricative. Thus, the process cannot be spreading a higher node in the tree, such as the supralaryngeal node, which would include manner features, nasality, etc. Third, the prefix nasals which are assimilating in place of articulation are tone-bearing and syllabic. Thus, the nasal-consonant sequences in (19) cannot be prenasalized stops, which would be derived by spreading [+nasal] onto the following stop, but rather must be derived by spreading the place features of the following stop onto the nasal, as in (20):

(20)
```
supralar.    supralar.
  ǂ              |
place          place
```

In Pame, also, nasals assimilate in place of articulation to following stops, fricatives, and liquids without losing their [-cont] degree of closure before the fricatives or the liquids (data from Gibson and Bartholomew (1979:310)):

(21)	ŋgobE?Et	'flag'	mbE?Et	(pl.)
	ŋgodEoc?	'bridge'	ndEoc?	(pl.)
	ŋgokwhe?	'bean'	ŋkhwe?	(pl.)
	ŋgosaon	'night'	nsaon	(pl.)
	ŋgolhwa	'ear of corn'	nlhwa	(pl.)

Thus, the assimilation in (21) must be spreading a constituent containing all the place features, but none of the manner features -- in particular, the manner features [cont] and [nasal] are not spread. Therefore, the constituent spread in (21) must be the place node.

Another example of place assimilation which must involve spreading the place node is that of Sanskrit, discussed in Steriade and Schein (to appear:47) and Steriade (1982:62). This rule optionally assimilates /s/ to the place features of a following obstruent, as the examples in (22) show.[12]

(22)

Indras	śuras	'the hero'		-->	Indraś śurah
tas	'those-fem'	ṣaṭ	'six'	-->	taṣṣaṭ
divas	'god-GENsg'	putras	'son'	-->	divaɸ putrah
Nalas	kamam	'at will'		-->	Nalax kamam

In the assimilations in (22), just as in the Kpelle and Pame assimilations, it must be the place node that is being spread. First, the /s/ assimilates to whatever place features there are: [coronal], [anterior], [distributed], [labial], and so on. Therefore, the assimilation in (22) cannot be spreading a particular place feature, but must rather be spreading the place node, containing all the place features of a segment. Second, only the place features of the following obstruent are spread onto the /s/. /s/ remains [+continuant] even when assimilated in place of articulation to a following stop, as in divaɸ putrah and Nalax kamam. Thus, the process cannot be spreading a higher node in the tree which would include manner features. Third, there is no question of the clusters in (22) being a merger of the features of /s/ onto the following obstruent (unlike Kpelle, where it had to be argued that the nasal-consonant sequences were not prenasalized segments). Thus, the process shown by the data in (22) must be a spreading of the place node, as in (20).

present further phonological evidence for the place node in my

----

12. All of these have alternate realizations in which the optional place assimilation fails to apply and the Visarga rule, deleting the supralaryngeal features of post-vocalic word-final /s/, applies instead, yielding /h/. The Visarga rule is also the source of the [h] in Indraś śurah and divaɸ putrah.

discussion of complex segments in Chapter 2.

The place node is also motivated by phonetics. Like the supralaryngeal node, the place node does not correspond to any articulator, but rather has acoustic motivation. Within the supralaryngeal node in the hierarchy, the place node is opposed to the soft palate node. While both nasality and place of articulation distort the shape of the formants, and hence are grouped under supralaryngeal, the distortions caused by each are quantitatively and qualitatively different. The distortions produced by place features have to do with changing the shape of the resonator, while those produced by nasality have to do with adding a second resonator.

1.2.3 Root Node

The last of the class nodes proposed by Clements is the root node, a constituent containing all the features of a segment. Clements argues that the root node is required for (i) total assimilation processes which create geminates by spreading the root node and (ii) being able to characterize the "phoneme" as the set of features dominated by the root. Other arguments for the root node can be found in the association to the skeleton of underspecified segments in root-and-pattern languages.

Root-and-pattern morphology means that the syllable structure, number of skeletal slots, etc., in a word are specified indepenoently, as a different morpheme from, the features of the units in the root melody. The root melody then associates one-to-one left-to-right to the independently specified skeleton, as in (23).

```
(23)    a   b   c       root melody
        |   |   |       automatic l-to-r association
        x   x   x       independent skeleton
            |
            R
```

For details on root-and-pattern morphology, see McCarthy (1979), Archangeli (1984).

I will assume the theory of underspecification developed in Archangeli (1984), by which only one value for any given feature may be specified in UR. I take this underspecification to apply to class nodes, also, so that if a segment is not distinctive for any glottal features, and if there is no contrast between having a laryngeal node without any features and having no laryngeal node, then it will not be represented with a laryngeal node. I shall argue that underspecification in UR will then require the existence of the root node in order to keep the features for each segment together prior to association to the skeleton.

I illustrate with an example from Yawelmani. Yawelmani has three series of stops: aspirate, glottalized, and intermediate (voiceless unaspirated). These will be represented in UR as [+spread], [+constr] and absence of laryngeal features (no laryngeal node), respectively.[13]

----

13. Yawelmani data is from Archangeli (1984). It is not crucial to my argument which series of stops is taken to be unspecified for laryngeal features, only that one of them be.

(24)

```
a.  Aspirate: /t/          b.  Glottalized: /t'/          c.  Intermediate: /d/

        root                       root                       root
        /  \                       /  \                          \
   laryng.  \                 laryng.  \                          \
     |    supralar.             |    supralar.                 supralar.
[+spread gl]               [+constr. gl]
```

Similarly, Yawelmani sonorants, which may be either glottalized or plain, will be represented with either [+constr] on the laryngeal tier, as in (24b), or with no laryngeal node at all, as in (24c). Finally, Yawelmani may have the segments /?,h/ in UR. These will be represented as simply [+constr] or [+spread] on the laryngeal tier, with no supralaryngeal node at all, as in (25).

```
(25)   a. /?/     root                    b.  /h/          root
                   |                                        |
               laryngeal                                laryngeal
                   |                                        |
             [+constr. gl]                            [+spread gl]
```

Given the underspecification in (24,25) above, the association of melody to skeleton in Yawelmani requires a root node. If there were no root node, then the laryngeal and supralaryngeal nodes would each associate independently, one-to-one and left-to-right, to the skeletal slots. The first laryngeal specification in the root would necessarily surface on the first skeletal slot, as would the first supralaryngeal specification. For example, without a root node, Yawelmani /?il/ 'fan' (p.27) would associate to the skeleton as in (26a), yielding an initial [l'], rather than as in (26b), the correct association:[14]

----

14. Glottalized [l] is a possible underlying segment in Yawelmani. Archangeli argues that consonants associate independently, on a different tier from vowels; thus the medial /i/ in /?il/ will not ensure the correct

```
(26)    a.  *                           b.   [+constr]  [lateral, ...]
                   [lateral, ...]               |               |
         [+constr]     |                        |          supralaryngeal
             |     supralaryngeal           laryngeal          /
             |        /                          \            /
          laryngeal  /                           root       root
                \   /                               \       /
                 C x C x x C                         C x C x x C
```

Similarly, without a root node, /doţ'ee/ 'bad' (p.337)[15] would associate yielding *[t'od̨ee], as in (27a), the [+constr gl] laryngeal node that should belong to the second consonant associating independently from left to right, and associating to the leftmost skeletal slot.

```
(27)    *     [+constr gl]
                      \   [+cor] [+cor]
                 laryng      |      |
                      \    supra  supra
                       \  /      /
                        C   x   C x x C
```

[t'] is a possible initial consonant, as in /t'ul/ 'burn' (p.127) or /t'it'iit'/ 'anus' (p.146). Thus, we could not prevent the incorrect associations in (26a) and (27) by preventing laryngeal and supralaryngeal from linking to the same x-slot, for they clearly would need to in order to form the initial /t'/ of /t'ul/.

Note that without a root node, /doţ'ee/ would associate incorrectly even if vowels and consonants were on the same tier, since /o/ would have no laryngeal features to block the [+constr gl] laryngeal node of /t'/ from associating to the leftmost slot, as shown in (28a). The correct

----

mapping of /?/ and /l/. C and x are shorthand used by Archangeli to refer to unsyllabified and rime x-slots, respectively. [ţ] is alveolar, [t] is dental.

15. [ţ] represents an alveolar stop, as opposed to dental [t].

association, with root nodes, is shown in (28b).

(28)

```
a.* [+constr gl]                              b.          [+constr gl]
       |   d      o     ḍ                          d      o       |      ḍ
   laryng.   /     /     /                         |      \    laryng.   /
       | supra. supra. supra.                    supra.  supra.     \    supra.
       |/    /     /                               |      |          \  /
       C      x     C  x  x  C                    root   root        root
                                                   |      |          /
                                                   C      x        C  x  x  C
```

(/d,ḍ/ plus [+constricted glottis] in (28) equal [t',ṭ'].)

Analogous to glottalization is aspiration. In /bint/ 'ask' (p.257), the first distinctive specification of laryngeal features is the [+spread gl] on the final /t/. Associating that laryngeal node independently from left to right would result in it associating to the leftmost slot in the skeleton, yielding *[pind], in exactly the same manner as in (28a).

Thus, we have seen that in a root-and-pattern language like Yawelmani, underspecification forces the root node, because if segments in the root melody are unspecified for either laryngeal or supralaryngeal features, then association one-to-one left-to-right without a root node will result in the leftmost skeletal slots being specified on both laryngeal and supralaryngeal tiers, followed by increasingly unspecified segments.

Unlike the laryngeal, supralaryngeal, and place nodes, the root node has no phonetic motivation. It is motivated solely by phonological phenomena such as those discussed above.

1.2.4 Manner Features

As mentioned above, the feature hierarchy Clements proposes divides the supralaryngeal features into two constituents: a manner node and a place node. The evidence presented above argues for the place node. However, there is no evidence from spreading processes, as Clements admits, for a constituent comprised of the features that Clements groups under "manner": continuant, consonantal, sonorant, nasal, lateral, strident. Thus, I will not assume a manner node under the supralaryngeal node, but will instead, given the absence of evidence as to the place or grouping of manner features in the hierarchy, make the simplest assumption -- that the individual manner features do not form a constituent, but are each linked directly and independently to the root node, as in (29):[16]

```
(29)               root
          laryng. supra. [cont] [cons]
```

I shall distinguish between the manner features in (29), [cont] and [cons], which specify articulatory degree of closure, and the manner features [sonorant] and [strident] which refer to acoustic properties of the segment and which may be implemented by different articulatory means. For example, [+sonorant] must be [+cont] if [-nasal], but may be [-cont] if

----

16. There is no evidence determining whether manner features should attach to the root node as in (29) or to the supralaryngeal node, as suggested in Clements (1985). For purposes of discussion, I represent the manner features on the root node here and throughout the thesis, but nothing hinges on this choice. All of the arguments would hold if they were represented on the supralaryngeal node.

[+nasal]. I propose a treatment for the degree of closure features [cont,cons] in Chapter 3, but will not deal with [son,strid]. The remaining manner features are [lateral] and [nasal]. [Lateral] will be discussed in the following chapter. As for [nasal], there is evidence that it must be represented under the supralaryngeal node, and not on the root node with [cont] and [cons]. This evidence comes from a set of processes in Klamath which have the effects in (30) (discussed in Clements (1985:234)):

```
(30)    nl      -->    ll
        nL      -->    lh               ([L] = voiceless l.)
        nl'     -->    l?
        lL      -->    lh
        ll'     -->    l?
```

As Clements shows, the processes in (30) may be characterized by the rules in (31a,b) (ignoring structure within the supralaryngeal node).

```
(31)    a.      root     root
                 ≠ _______|
                supra    supra
                 |        |
                [+son]   [+lat]
                [+cor]
                [+ant]

        b.      root     root
                   \     ≠   \
                    \   /     laryngeal
                    supra
                      |
                    [+lat]
```

(31a) spreads the supralaryngeal node of a lateral onto the segment to its left provided that segment is an alveolar sonorant. (31b) delinks the supralaryngeal features of the right half of a geminate lateral if it has distinctive laryngeal features specified. What concerns us here is (31a).

Note that spreading the supralaryngeal node as in (31a) results in the deletion of the nasal features of the first segment in the first three examples in (30). Since it is the supralaryngeal node that is spread, triggering the delinking of the original supralaryngeal node of the first segment, this shows that [+nasal] must be specified within the supralaryngeal node. If it weren't, then in order to automatically delink [+nasal] we would have to spread and delink the root node, including laryngeal features, which would be incorrect. This process also shows that [lateral] must be under supralaryngeal in the hierarchy, and not linked to the root node with [cont] and [cons].[17]

Rather than representing [nasal] as a terminal feature linked directly to the supralaryngeal node, I introduce a class node, the soft palate node, which links to the supralaryngeal node and to which [nasal] links. The soft palate node is analogous to the laryngeal node which refers to the independent articulator, the larynx, and to the articulator nodes labial, coronal, and dorsal, to be argued for in Chapter 2. The hierarchy I propose contains a class node for each independently functioning articulator in the vocal tract. Since the soft palate is an independent articulator, there is

----

17. An alternative would be to spread the entire root node in (31a), and then to diphthongize supralaryngeal and laryngeal features as in Icelandic Preaspiration. This alternative would not necessarily entail that nasal and lateral are within the supralaryngeal node, because the diphthongization could be a spreading of the laryngeal node to the right, rather than a spreading of the supralaryngeal node to the left. Note that this alternative would have the welcome result of explaining why diphthongization does not occur if there are no distinctive laryngeal features and no laryngeal node. If there is no laryngeal node, there is none to spread. In (31b), Clements' version, however, the laryngeal node is an added stipulation on the rule.

a class node in the hierarchy for the soft palate. Since the soft palate node dominates only the feature [nasal], there will be no evidence for it from spreading two features at once, as there was for, e.g., the place node. Spreading the soft palate node will be indistinguishable from spreading the single feature [nasal] under it in almost all cases. The only case of spreading which would provide evidence for the soft palate node as a constituent would be one where a prenasalized segment spread both [-nasal] and [+nasal] onto an adjacent segment -- i.e. where the branching structure [+nasal][-nasal], or prenasalization, were assimilated, as in (32):

```
(32)    root    root
          |       |
        supra   supra
          ≠       |
      soft-pal  soft-pal
                  / \
            [-nas] [+nas]
```

I know of no such example. Nevertheless, I will maintain the hypothesis that there exists a class node for the soft palate articulator.

Therefore, the hierarchy argued for so far is that in (33) (ignoring features within the laryngeal and place nodes):

```
(33)                x
                    |
                   root
                  /    \
    laryngeal  supra.  [cont]  [cons]
                / \
         soft-pal  place
            |
         [nasal]
```

1.3 Contour Segments

Recall that a contour segment is represented as branching for some feature, i.e.

```
(34)   a.      x               b.      x                c.       x
              / \                     / \                       / \
        [-cont] [+cont]        [-stiff] [+stiff]          [+nasal] [-nasal]
```

(34b) represents a contour tone rising from mid to high, under the feature proposals in Halle and Stevens (1971) whereby high pitch in vowels is represented by the feature [+stiff vocal cords] and low pitch by the feature [+slack vocal cords]. Evidence for representing the tones of vowels on the laryngeal tier with the same features as are used for consonants, rather than on a separate tonal tier with unrelated features, comes from languages where tones and laryngeal features interact. For example, in Chinese and in Nama, voiced consonants lowered the tones of following vowels. (For further discussion, see Beach (1938), Greenberg (1970), Halle and Stevens (1971).)

However, with phonological features represented hierarchically, as argued in this chapter, contour segments can no longer be represented as in (34), in which the branching features link directly to the skeleton, because features no longer link directly to the skeleton. Rather, in a hierarchical representation, there will be ambiguity as to exactly at which level in the hierarchy the contour segment is branching. (34a,b,c) will be ambiguous in the ways shown in (35,36,37).

```
(35)
a.      x                b.      x
       / \                       |
   root  root                   root
     |     |                    /  \
 [-cont] [+cont]          [-cont] [+cont]

(36)
a.      x                b.      x               c.      x
       / \                       |                       |
   root  root                   root                   root
     |     |                    /  \                     |
  laryn. laryn.           laryn.   laryn.             laryng.
     |     |                 |       |                 /   \
[-stiff] [+stiff]        [-stiff] [+stiff]       [-stiff] [+stiff]

(37)
a.      x           | b.     x          | c.      x          | d.      x
       / \          |        |          |         |          |         |
   root  root       |      root         |       root         |       root
     |     |        |      /  \         |         |          |         |
  supra  supra      |  supra  supra     |       supra        |       supra
     |     |        |    |      |       |       /  \         |         |
soft-pal soft-pal   |soft-pal soft-pal  |soft-pal soft-pal   |     soft-pal
     |     |        |    |      |       |    |      |        |       /  \
[+nasal][-nasal]    |[+nasal][-nasal]   | [+nasal][-nasal]   |[+nasal][-nasal]
```

Obviously, no language makes use of the distinctions among, e.g. (37a,b,c,d). It would therefore be preferable if our feature representation did not predict a distinction among them. As a means of restricting the possible types of contour segments predicted by the hierarchical representation, I make the following hypothesis:

(38) Contour segments may branch for terminal features only. No branching class nodes are allowed.

I make the restriction in (38), rather than, for example, restricting contour segments to branching root nodes, because it can be demonstrated that branching terminal features are required. For example, in Guarani, prenasalized stops are derived by a process of nasal harmony that spreads just the feature [nasal]. Thus, the resulting prenasalized stop must be branching just for the feature [nasal], and not for any class nodes. The derivation of prenasalized stops by the linking of [-nasal] from a following oral vowel onto a nasal consonant is shown in (39) (from van der Hulst and Smith (1982:325)):[18]

```
(39)   a.      +     -               +     -
               |                     |     |
               ne-tupa     ==>       ne-tupa        [ndetupa]   'thy bed'

       b.      +     +               +     +
               |                     |     |
               ne-tupa     ==>       ne-tupa        [nẽtũpã]    'thy god'
```

Since the prenasalized stop in (39a) is derived from a nasal consonant by spreading of just [-nasal], it must be represented as branching only for the feature [nasal], as in (37d), and not as in (37a,b,c).

Also, it is clear that contour tones must be represented as branching just for the features [stiff] and [slack], and not for the laryngeal or root nodes, because tone spreading is not blocked by intervening laryngeal or root nodes.

Thus, since there exist contour segments which must be represented as branching for a terminal feature, I will restrict the possible branchings in contour segments by ruling out all but branchings to terminal features.

Also, since each branching in a contour segment complicates the structure, we may consider each branching to come at a cost. Limiting branchings to terminal features thus explains why contour segments generally branch only for one feature, for example, usually sharing

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18. Thanks to Donca Steriade for pointing out this example.

laryngeal features. By contrast, if branching root nodes were allowed, we would expect any two segments in totally random combinations to occur on a single x-slot as a contour segment, possibly having no features at all in common.

1.4 Overview

In the following chapters, I will offer evidence for other aspects of the representation in Figure 1, namely, the structure within the place node, the representation of manner features on the root node, and the relation between the root and articulator nodes. Crucial tc my argument is evidence for the feature geometry of a different type than has been presented so far: evidence from segments with multiple articulations within the place node, or complex segments, which make unique demands on the feature geometry.

In the following chapter, I investigate the representation of place of articulation features in complex segments. I show that they mu be analyzed as having phonologically unordered articulations within a single place node, unlike contour segments, which have phonologically ordered articulations. Furthermore, I show that the structure within the place node required by complex segments finds independent support in languages without complex segments, and thus that it is a universal property of the representation of distinctive features, rather than a peculiarity of complex-segment languages.

I then propose, in Chapter 3, a representation for degree of closure features that can account for the behaviors of complex segments. Complex segments offer crucial evidence regarding the role of degree of closure features in the hierarchy, a problem that has until now remained unsolved. The modifications of the feature representation that are necessary to represent and account for the behavior of complex segments lead to a concise characterization of the possible complex segments in human language.

In Chapter 4, I redefine the distinctive features in light of the proposals made in Chapters 1, 2, and 3. Chapter 5 contains a demonstration that the association lines among features and x-slots that conect all the tiers in Figure 1 must represent the relation of overlap in time. I also show in that chapter that when association lines are correctly defined as representing overlap, the ill-formedness of crossing association lines follows from the relations represented in a phonological representation, together with knowledge of the world, and need not be stipulated as a well-formedness condition in UG. Finally, in Chapter 6, I discuss two aspects of phonetic representation that are made possible by the view of phonological representations taken in Chapters 1 through 5 -- degrees of closure of individual articulators and subsegmental timing.

Appendix A

Notation

Throughout this thesis, unless otherwise noted, I use the following notation:

Nasals	ɱ	--	labiodental nasal [ɱ]
	ñ	--	palatal or palatoalveolar nasal
	ŋ	--	velar nasal [ŋ]
Fricatives	ɸ	--	bilabial fricative, voiceless
	B	--	bilabial fricative, voiced [β]
	ʂ	--	retroflex fricative, voiceless [ṣ]
	ʐ	--	retroflex fricative, voiced [ẓ]
	š	--	palatoalveolar fricative, voiceless [š]
	ž	--	palatoalveolar fricative, voiced [ž]
	ɬ	--	lateral fricative, voiceless [ɬ]
	ɮ	--	lateral fricative, voiced [ɮ]
	ç	--	palatal fricative, voiceless
	ʝ	--	palatal fricative, voiced
	Y	--	velar frictive, voiced [ɣ]
Affricates	¢	--	alveolar affricate, voiceless
	ʣ	--	alveolar affricate, voiced
	č	--	palatoalveolar affricate, voiceless [č]

	ǰ	--	palatoalveolar affricate, voiced [ǰ]
Stops	c	--	palatal stop, voiceless
	j	--	palatal stop, voiced
	g̑	--	fronted velar stop, voiced
	k̑	--	fronted velar stop, voiceless
Vowels	I	--	lax high front vowel
	E	--	lax mid front vowel
	O	--	lax mid back rounded vowel
	U	--	lax high back rounded vowel
	ɨ	--	high back unrounded vowel
	ɨ	--	lax high back unrounded vowel
	y	--	high front glide

Chapter 2

COMPLEX SEGMENTS AND PLACE FEATURE GEOMETRY

As shown in the previous chapter, the many-to-one linkings within a single segment made possible by autosegmental representations have proved useful for two classes of segments. First, contour segments such as affricates and prenasalized stops are represented by many-to-one linkings of sequences of articulations within a single segment. Second, the common combination within a segment of simultaneous and independent laryngeal and supralaryngeal articulations (or nasal and place articulations) is represented by the hierarchical feature geometry of Clements, in which laryngeal and supralaryngeal features (or nasal and place features) are independent of each other in the hierarchy and thus may cooccur freely. There is, however, a class of segments which is accounted for neither by the sequential multiple linkings in a contour segment, nor by the simultaneous multiple linkings in Clements' hierarchy. This is the class of segments involving multiple articulations within a single segment which are not in sequence but which may not be split into laryngeal and supralaryngeal (or nasal and place) articulations. These segments, involving multiple simultaneous articulations within the place node, I will call "complex segments". Some examples of complex segments are given in (1).

(1)

a.	labial + coronal	Bura	[ptá]	'(an animal)'
b.	labial + velar	Yoruba	[akpá]	'arm'
c.	coronal + velar	Nzema	[opti]	'it is thick'
d.	labial + coronal + velar	Shona	[tkwana]	'little children'
e.	labial + velar click	!Xoo	[ʘʔόo]	'be stuck'
f.	coronal + velar click	Nama	[ǀui]	'one'

In this chapter, I propose a geometry for place of articulation features based on the requirements of representing complex segments, of deriving them correctly where they are not underlying, and of accounting for their behavior with respect to the phonological processes of the languages they occur in. Furthermore, the representation I propose -- a hierarchical structure within the place node with an independent node for each articulator -- is shown to have independent support in languages without complex segments. Thus, articulator nodes under the place node are proposed to be part of the universal hierarchical representation of features, and are not restricted to the feature representations of complex segment languages. The articulator nodes representation also provides us with a straightforward characterization of the dependence of features such as [round] and [anterior] on the features [labial] and [coronal], respectively, where specification for the former implies positive specification for the latter.

2.1 Structure within the Place Node: Articulator Nodes

Consider the types of complex segments that are attested in human language. It is certainly not the case that any two consonants that occur in human language may be combined in some language as a complex segment.

Rather, the possible complex segments in human language form a restricted class, including such segments as listed in (1) above, but excluding such combinations of articulations as bilabial plus labiodental (e.g. [ɸf]), alveolar plus dental (e.g. [θs]), or palatal plus velar (e.g. [ck]). The reason for these gaps in the class of possible complex segments is explained by Halle (1982) as follows:

> Consonantal occlusions are thus produced by three distinct active articulators: the lower lip, the front part of the tongue, and the tongue body. Since the position of each of these three articulators is independent of the other two it should be possible to produce consonants with more than one occlusion. Since there are three active articulators and since a given articulator can be only at one point at a given time there should exist three types of consonants with double occlusion and a single type of consonant with triple occlusion. As shown in (2) all double occlusion consonants are attested, but I have been unable to find an example of a consonant with triple occlusion.

(2)	labio-velars	[kp]	Yoruba	[akpa]	"arm"
	labio-coronal	[pt]	Margi	[ptəl]	"chief"
	corono-velar	[ǀ] (click)	Zulu	[ǀaǀa]	"climb"
	labio-corono-velar	(unattested)			

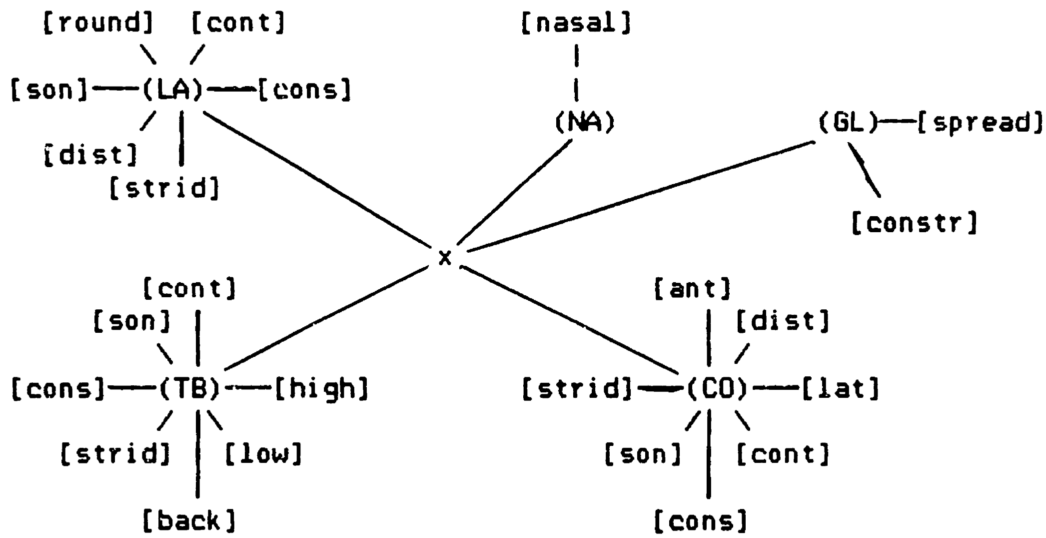
(p.98-9)

In Sagey (1984), I propose an analysis of Kinyarwanda involving such consonants with multiple occlusion, or complex segments. The complex segments I propose there for Kinyarwanda not only conform to the types of multiple occlusions that Halle presents as articulatorily possible, but they also fill the gap that Halle lists as unattested: the initial consonant in Kinyarwanda [tkwaaŋga] 'we hate' is exactly the labio-corono-velar that the articulatory facts predict should exist.

Thus, the class of possible complex segments in human language is explained by the fact that speech is produced using several independently functioning articulators in the vocal tract. Of course, this anatomic independence need not in itself have entailed any phonological independence among the articulators. Universal Grammar could have been such that even though the articulators are physically independent, the language faculty could make no use of that independence, being capable only of representing linear sequences of single articulations. However, the facts just noted show this is not the case, and that the phonologies of human languages do make use of the independence of these articulators. Thus, our feature geometry needs to reflect the articulatory independence of the lips, tongue front, and tongue body.

To capture this articulatory independence in the feature geometry, in Sagey (1984) I propose a feature geometry with an independent tier for each independently functioning articulator, and with manner features represented independently for each articulator. The structure I propose is that in (3). (The "Articulator-Tiers" in (3) are: LA = labial (lips), NA = nasal (soft palate), GL = glottis, TB = tongue body, and CO = coronal (tongue front).)

(3) Articulator-Tiers



However, the arguments presented in Chapter 1 for the hierarchical constituents root, laryngeal, supralaryngeal, and place show that the geometry in (3) is not quite correct. Rather, the articulator tiers in (3) must be grouped hierarchically. Thus, I adapt the structure in (3), with independent tiers for the glottis, soft palate, lips, tongue front, and tongue body, into the hierarchical structure argued for in Chapter 1, yielding the structure in (4).[1] (I abandon in (4) the representation of independent manner features for each articulator shown in (3). I will discuss in Chapter 3 the position in the hierarchy of manner, or degree of closure, features.)

----

1. See Halle (1986) for a similar proposal.

(4)

```
                         root
                        /    \
             laryngeal         supralaryngeal
            / /  |  |          /            \
     constr  /   |  |     soft-palate        place
       spread    |  |          |            /  |  \
           stiff    |        nasal      labial  |   \
               slack                     /      |    dorsal
                                     round      |    | \  \
                                             coronal |  \  back
                                              /  \   high low
                                            ant dist
```

Given the structure in (4), a complex segment will be represented as having two articulator nodes under the place node, as does /kp/ in (5).

(5) /kp/

```
        x
        |
       root
        |
      supra
        |
      place
       /  \
  labial   \
          dorsal
```

Under the assumption that only terminal nodes, and not class nodes, may branch in a contour segment, which was argued for in the previous chapter as necessary in order to restrict the possible contrasts among contour segments, it is impossible to represent /kp/ as a contour segment, with phonologically ordered articulations. Such a representation would have to be as in (6a), (6b), or (6c), all of which contain branching class nodes and are thus excluded by the assumption argued for.

```
(6)   a. *   x               b. *   x               c. *   x
            / \                     |                      |
        root   root               root                   root
         |      |                 /  \                     |
       supra  supra           supra  supra               supra
         |      |               |      |                 /   \
       place  place           place  place           place   place
         |      |               |      |               |       |
      dorsal    |            dorsal    |            dorsal     |
              labial                 labial                  labial
```

Thus, the representation on a single x-slot of multiple articulations formed by different articulators requires that those articulations are phonologically unordered, a result that is supported by evidence to be presented below.

The restriction against branching class nodes also rules out contrasts between, e.g., (7a) and (7b), or among (8a), (8b), and (8c). Only (7a) and (8a) are allowed.

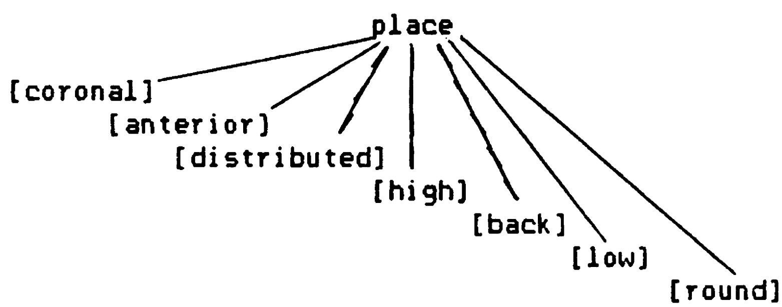
```
(7)   a.     x               b.      x
             |                      / \
            root                 root root
            /  \                  |    |
       laryng   \             laryng   |
               supra                 supra

(8)   a.     x               b.      x               c.      x
             |                       |                      / \
            root                    root                root   root
             |                      /  \                 |      |
            supra               supra  supra           supra  supra
            /   \                 |      |               |      |
     soft-pal    \           soft-pal    |          soft-pal    |
                place                  place                  place
```

In the following sections, I present phonological arguments for the structure within the place node in (4).

2.2 Articulatory Independence -- Possible Complex Segments

First, as already noted, the articulator nodes structure in (8) provides an explanation for the class of possible complex segments in human language. Consider a representation without articulator nodes, i.e. with the standard place of articulation features proposed in SPE. Such a representation, as assumed by Clements in his hierarchy, would represent place features under the place node as in (9):

(9)



The set of place features in (9) distinguishes labials, alveolars, alveopalatals, and velars by the feature values in (10):

(10)

a. labial	b. alveolar	c. alveopalatal	d. velar
[+anterior, -coronal]	[+anterior, +coronal]	[-anterior, +coronal]	[-anterior, -coronal]

One problem with (10) is that it provides no characterization of the fact that alveolars and alveopalatals may not combine in complex segments, while any other combination in (10) is possible. With the articulator nodes structure in (4), however, this fact is characterized by the fact that complex segments are possible only for combinations of two different articulators. Alveolars with alveopalatals are impossible because both are formed with the coronal articulator.

A more serious problem with the representations in (10) is in the actual feature representation of a complex segment. Consider, for example, a labiocoronal such as Margi [pt] or Nzema [pt]. By the feature representations in (10), a labiocoronal must be both [+anterior,-coronal] and [+anterior,+coronal]. I show below that the two articulations in, e.g., Margi [pt] must be simultaneous (to account for [pt] becoming [mnpt] when prenasalized); therefore, we cannot represent [pt] as a contour segment as in (11).

(11)

$$\begin{bmatrix}\text{+anterior}\\ \text{-coronal}\end{bmatrix} \begin{bmatrix}\text{+anterior}\\ \text{+coronal}\end{bmatrix}$$

\ /

place

However, we cannot represent the feature specifications in (11) simultaneously, either, because that would require the segment to be simultaneously [-coronal] and [+coronal], as in (12), where the two specifications for [coronal] are unordered.

(12) [-coronal]

\ [+coronal]

\ /

place

A structure such as (12) would be impossible to interpret phonetically. The feature specifications [-coronal] and [+coronal] contradict each other.

The solution to this problem lies in realizing that it is really irrelevant to the articulation of the labial closure (i.e. to the behavior of the lips) whether or not there is additional [+coronal] closure. Therefore, a lack of coronal closure should not be part of the universal definition for a labial, indeed its defining characteristic, as it is when we define a labial as [+anterior, -coronal].[2] We might solve this problem by introducing a feature [labial], as has been proposed by many researchers. But then we would have to specify the coronal as [-labial], and [pt] would contain the feature contradiction [+labial] and [-labial]. Again, however, it is irrelevant to the articulation of the alveolar closure (i.e to the behavior of the tongue front) whether or not there is additional [+labial] closure. Therefore we should remove [-labial] from the definition of the alveolar. In short, the problem with the feature specifications in (9) is that they define segments, not simply in terms of what constrictions or articulators are involved, but also in terms of what is not involved.

What is required, therefore, is that the place of articulation features for an articulation must contain only positive specifications of articulations required and relevant to that articulation, and not features for what articulations are absent. The representation of complex segments requires the following degree of underspecification: the absence of an articulation is never specified. If the absence of an articulation is specified as part of the representation of a segment, that is equivalent to claiming that that articulation may never cooccur as a coarticulation with

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2. Language-particular restrictions may, however, disallow the combination [+labial, +coronal].

that segment.

This requirement is satisfied as a natural consequence of the representation proposed above, by which labial, coronal, and dorsal are not features, which may be specified + or -, but are class nodes, which may only be either present or absent in the representation. There is no representation for [-coronal] under the articulator nodes representation in (11). Rather, a labial simply contains a labial class node under the place node. Likewise, a coronal simply contains a coronal class node under the place node, and is not specified as [-labial]. The combination of a labial and a coronal articulation in a single segment, therefore, is represent by a place node with both a labial node and a coronal node. Since labials and coronals are defined just by the presence of a labial or a coronal node, respectively, and not by the absence of any other node, there is no contradiction in a representation with both.

Under the representation in (4), labials, alveolars, palatoalveolars, and velars will be distinguished as in (13):

(13)

```
a.  labial        b.  alveolar        c.  alveopalatal        d.  velar

    place             place               place                   place
      |                 |                   |                       |
    labial            coronal             coronal                 dorsal
                        |                   |
                    [+anterior]         [-anterior]
```

This interpretation of articulator nodes -- as being present only when the articulator is involved as an active articulator in the segment -- entails a basic difference between class nodes in the hierarchy, such as articulator nodes, and standard features -- the terminal nodes in the hierarchy. While the features on the terminal nodes, such as [anterior], [round], etc., may be specified as either '+' or '-', the class nodes may not. Rather, class nodes are either present (denoting active involvement of an articulator), or absent (denoting no active involvement by the articulator), as shown by the representations in (13), in which, e.g., the labial segment contains neither the coronal nor the dorsal articulator nodes.

An advantage of the representation in (13) is that it allows a straightforward structural characterization of languages which allow no complex segments. Such languages simply allow only one articulator node under the place node, resulting always in simple segments only. This characterization is not easy to represent if [coronal], [labial], etc. are just like the other features, which may cooccur in such languages, e.g. [+spread glottis] and [+back], or [+nasal] and [+anterior].

Also easily characterized are restrictions such as exist in the languages in (14), in which only labial consonants may be rounded, not coronals or dorsals. In (14) are given the relevant parts of the consonant inventories, from Ruhlen (1975).

(14)	a.	Aneityum	p	t	č	k
			bw			
			m	n	ň	ŋ
			mw			
	b.	Dogrib	ɸ	s	š	x
			ɸw			

c.	Iai	b	d	d	g	
		bw				
		m	n	ɲ	ŋ	
		mw				
		m̥	n̥	ɲ̥	ŋ̥	
		m̥w				
d.	Nenema	p	t	c	k	
		pw				
		ph	th		kh	
		phw				
		mb	nd	ɲj	ŋg	
		mbw				
		m	n	ɲ	ŋ	
		mw				
		m	n		ŋ	
		mw				
						h
						hw
e.	Ulithian	m	n		ŋ	
		mw				
		m:			ŋ:	
		m:w				

Under an articulator nodes structure, the restriction in the languages in (14) is simply that there may be only one articulator under the place node. Since [round] entails specification of the labial articulator node, combining round with coronal or dorsal would result in two articulator nodes. Only adding [round] to a labial can be done with a single articulator node, since [round] is under the labial node. In Nenema, shown in (14d), it is clear that the restriction is on the number of articultors under the place node, and not, e.g., that only labials may be labialized. For in addition to the labialized labials in Nenema, there exists a labialized [h]. Since [h] lacks supralaryngeal features, in particular lacking any articulator node, adding [+round] and a labial articulator node to [h] results in a place node with only one articulator node under it -- the labial node added with rounding.

2.2 Articulatory Independence -- Possible Complex Segments

In the following sections, I establish that complex segments have the the following properties: First, like contour segments, complex segments are not consonant clusters, but are in fact single segments. Second, complex segments are distinct from contour segments in that their articulations are not phonologically in sequence, but are simultaneous or unordered. Third, the multiple articulations in a complex segment must be represented under a single place node, rather than being, e.g., two root nodes linked to one x-slot. I will show in each instance that the articulator nodes structure proposed above provides a straightforward characterization of the above properties.

2.3 Clusters vs. Contour or Complex Segments

In this section, I establish that complex segments are like contour segments (and unlike consonant clusters) in that they must be represented on a single x-slot.

2.3.1 Syllable Structure

The representational difference between a cluster of two consonants and a contour or complex segment is that the former is mapped onto two x-slots, and is hence syllabified as two segments, while the latter is mapped onto a single x-slot, and hence is syllabified as one segment. Thus, evidence from syllabification can tell us whether we are dealing with a consonant cluster or with a contour or complex segment.

Consider, for example, the syllable structure of Kinyarwanda, an eastern Bantu language spoken in Rwanda. Like many Bantu languages, Kinyarwanda has only open syllables (cf. Kimenyi, p.8; Sibomana, p.12); the only branching rimes allowed are geminate vowels. However, a first look at a typical word in Kinyarwanda seems to suggest quite complex consonant clusters, of which all the consonants would be syllabified into the onset, since Kinyarwanda has only open syllables.

(15)	u.mu.ga.bo	"man"
	i.mŋee.ru.mŋe	"male dog"
	u.bgaa.nŋwa	"beard"
	kwaa.ka	"to ask"
(16)a.	tkwaa.ŋga	"we hate"
	mŋaa.nho.re.ye	"you (pl.) worked for me"
	nda.me.sa	"I wash"
b.	ka.rii.ndgwi	"seven"

The words in (15) are given by Kimenyi (p.7) as illustrations of syllabification. The initial clusters in the words in (16a) confirm that the clusters in (15) (if they are clusters) can indeed be syllable-initial. (16b) illustrates an apparent four-segment onset.[3] The syllabifications postulated in (15,16), if they involved consonant clusters, would be extremely rare among the world's languages, and hence would be marked.

On the other hand, the syllabification in Kinyarwanda of loan words with consonant clusters shows a pattern in which almost no clusters are allowed. This contrasts with the complex clusters seen above. Thus, the

----

3. In Kinyarwanda, nasals cannot be in the rime; they do not bear surface tones and are not syllabic.

rg and the st in Burgermeister are split by epenthesis, yielding [burugumesitiri]. Similarly, the ks in Alexander is split, yielding [aregisaanderi].[4] Even loan-word clusters which would, by any theory of markedness, be less marked as onset clusters than the apparent clusters in (15,16) are split by epenthesis, as shown by the syllabifications in Kinyarwanda of the German loans in (17):

(17)

Republik	>	repuburika	Petroleum	>	peeteroori
Präsident	>	perezida	Präfekt	>	perefe
Patrizia	>	paatirisiya			

Thus, the pattern of syllabification in loan words points to a different inventory of possible syllable types for Kinyarwanda than that proposed by Kimenyi: rather than CCCCV(V) syllables, we see a maximal syllable of just CV(V).

These data from the loan words are consistent with Sibomana's description of the syllable structure of Kinyarwanda. He states:

> "das Kinyarwaanda hat zwei Silbenarten: V-Silben, die nur aus einem Vokal bestehen, und KV-Silben, Verbindung eines Vokals mit einem Konsonanten" (p.12, emphasis added).

I therefore conclude, based on syllable-structure markedness, loan word syllabification, and Sibomana's description, that CCV, CCCV, and CCCCV are not possible syllables in Kinyarwanda. However, if the maximal syllable in Kinyarwanda is CV(V), the words in (15) and (16) cannot be analyzed as containing consonant clusters: a syllable such as tkwaa in

----

4. I will argue below that the [nd] in [aregisaanderi] is a single, prenasalized, consonant, and not a cluster.

(16a) does not conform to the requirement for a maximum onset of one consonant if [tkw] is analyzed as a consonant cluster. Rather, the evidence from syllabification in Kinyarwanda suggests that the onsets in (15,16) must be either complex or contour segments -- single segments with multiple articulations.

Another Bantu language, similar to Kinyarwanda in the types of complex onsets it allows, is Shona. In Shona are found such syllabifications as those in (18):

(18)	mŋa.na	'child'
	nŋwa	'(to) drink'
	pka	'(to) dry up'
	rgwa	'(to) fight'
	nzYwa	'(to) hear'
	i.mbYa	'dog'
	hu.skwa	'grass'

As in Kinyarwanda, however, there is evidence that the complex onsets in (18) must be single segments, rather than clusters. This evidence is the fact that Shona has strictly CV syllable structure, disallowing all coda consonants and onset clusters, which can be clearly seen in its syllabification of loan words. As Doke notes, "when foreign words are imported into a Bantu language it is the rule that such words should be made to conform to the phonetic principles which govern the language. For this reason all European words which end in closed syllables demand a final vowel in Bantu ... [and] non-Bantu combinations of consonants must be divided by vowels" (p.226). That is, one of the "phonetic principles" which govern Shona is that closed syllables and onset clusters are disallowed, as is shown by the syllabifications of loan words in (19):

(19)	a.	No codas:	book	›	buku
			kat (Afrikaans)	›	i:k'a:t'i
			lamp	›	rambi
			pump	›	mbombi, popi[5]
			tent	›	tende
			location	›	rukiȼeni
			baptise	›	babatiʒa
			doctor	›	dokotera
	b.	No onset clusters:	tronk (Afr.)	›	torongo
			broek (Afr.)	›	buruku
			knoop (Afr.)	›	konobo

Again, note that the onset clusters split by epenthesis in (19b), /tr/, /br/, and /kn/, are, by any measure of syllable structure markedness, less marked than the onsets in (18) would be if they were consonant clusters. Thus, the syllable structure of Shona requires that the onsets in (18) be single segments, i.e. represented on single x-slots.

2.3.2 Compensatory Lengthening

Another source of evidence for the complex onsets in the previous section being represented on single x-slots, i.e. as either contour or complex segments, is the distribution of the complex onsets with respect to compensatory lengthening.

For example, in Kinyarwanda, complex onsets are derived from underlying sequences of segments, on more than one x-slot. That they are on the surface represented on single x-slots is shown by the fact that they

----

5. The nasal consonant sequences in these words are single segments -- prenasalized stops.

are always accompanied by compensatory lengthening of either the preceding or the following vowel, depending on the type of complex onset. The types of complex onsets (contour or complex segments) in Kinyarwanda are those derived from a sequence of a consonant and an unsyllabified vowel, and those derived from a nasal-consonant sequence. Some fall into both classes, being derived from a preceding nasal as well as a following vowel.

 CV′
NC
NCV′
N V′

The consonant-unsyllabified vowel type of complex onset in Kinyarwanda is derived from an underlying sequence of a consonant followed by two vowels. In such a sequence, the second of the two vowels syllabifies as the nucleus, taking the consonant as its onset. That the first vowel is not syllabified as a separate segment, i.e. a glide, is shown by the fact that there is always compensatory lengthening of the second vowel in this environment.[6] I analyze this in Sagey (1984) as follows: The first vowel's features surface by being linked to the x-slot of the consonant. The original x-slot of the first vowel is then filled by spreading the second vowel's features, resulting in compensatory lengthening.

----

6. Compensatory lengthening fails to show up only word-initially and word-finally, in which environments there are never long vowels, whether underlying or derived. The failure of compensatory lengthening in these environments is therefore irrelevant.

```
(20)    C V V           C V V   CL      C V V
        | | |   ===>    |/  |   ===>    |/ /|
        x x x           x x x           x x x
        |   |           |   |           |  \|
        O   N           O   N           O   N
         \ /             \ /             \ /
          σ               σ               σ
```

Some examples of the process shown in (20) are given in (21) (from Kimenyi p.16):

```
(21)    /ku-i-Bon-a/     [kwiiBona]      'to see oneself'
        /ku-gu-ir-a/     [kugwiira]      'to fall on'

        k u g u i r a   CSF   k u g u i r a   CL    k u g u i r a
        | | | | | | |   ===>  | | |/  | | |   ===>  | | |/ /| | |
        X X X X X X X         X X X X X X X         X X X X X X X
```

Similarly, the nasal-consonant type of complex onset, which is derived from a sequence of a nasal and a consonant, is always accompanied by compensatory lengthening of the preceding vowel. In the derivation of nasal-consonant clusters, then, the features of the nasal are realized on the x-slot of the consonant, and the features of the preceding vowel spread to fill the original x-slot of the nasal, resulting in compensatory lengthening.

```
(22)     V N C                    V N C                    V N C
         | | |                    |  \|         CL         |\ \|
     ... x x x ...    ==>     ... x x x ...     ==>    ... x x x ...
         |   |                    |   |                    |/  |
         N   O                    N   O                    N   O
         |    \ /                 |    \ /                 |    \ /
         σ     σ                  σ     σ                  σ     σ
```

Examples of this compensatory lengthening are given in (23).

```
(23)    /imi-nsi/        [imiinsi]       "days"
        /ba-nde/         [baande]        "who?"
        /ku-ngana/       [kuuŋgana]      "to be equal"

        k u n g a n a          k u n g a n a   CL     k u n g a n a
        | | | | | | |   ===>   | |  \| | | |   ===>   | |\ \| | | |
        x x x x x x x          x x x x x x x          x x x x x x x
```

An identical process of compensatory lengthening, both with nasal-consonant sequences and with consonant-vowel sequences, occurs in the related Bantu language of Luganda. Compensatory lengthening in Luganda is discussed by Clements (1978,1986), who independently arrives at a similar analysis to that given in Sagey (1984) for Kinyarwanda. Thus, in (24a) below, the features of the first vowel in each word link to the initial consonant, and in (24b) the nasal features link to the following consonant. These linkings are accompanied in both cases by compensatory lengthening, which spreads the neighboring vowel's features onto the empty x-slot. Clements gives the examples in (24a,b), which are derived structurally as shown in (25a,b):

```
(24)    a.     /li-ato/        [lyaato]        'boat'
               /mu-iko/        [mwiiko]        'trowel'
        b.     /ba-ntu/        [baantu]        'people'
               /ba-N-goba/     [baaŋgoba]      'they chase me'
           (Cf. /ba-goba/      [bagoba]        'they chase')

(25)    a.     l i a t o              l i a t o
               | | | | |              |/ /| | |
               x x x x x      ==>     x x x x x

        b.     b a n g o b a          b a n g o b a
               | | | | | | |          | |\ \| | | |
               x x x x x x x  ==>     x x x x x x x
```

2.3.3 Urhobo Nasal Harmony

In Urhobo, there is a process of nasal harmony which distinguishes between a labialized consonant on one x-slot vs. a sequence of consonant plus /w/ on two x-slots. Nasal harmony spreads nasalization over a stretch of vowels or over the consonants /B,y,r,w/. (/B/ in Urhobo is a bilabial approximant, not a fricative (Ladefoged (1968:26).) Examples of nasal harmony are given in (26) (data from Kelly (1969)):[7]

(26)

a.	/uyoBin/	[ũɥ̃õɥ̃ĩ]	'head'
b.	/ewan/	[ẽw̃ã]	'to clear bush'
c.	/ewen/	[ẽw̃ẽ]	'breath'
d.	/oRwen/	[oRw̃ẽ]	'hunter'
e.	/iRirin/	[iRĩr̃ĩ]	'nine'
f.	/evun/	[evũ]	'belly'

(26a) shows nasalization spreading over /B/. (26b,c) show nasalization spreading over /w/. (26d) shows that /w/ need not be intervocalic in order to become nasalized. It is nasalized in [oRw̃ẽ], despite the preceding non-nasalizable voiceless /R/. (26e,f) show that nasal harmony is blocked by non-nasalizable /R,v/. Thus, the data in (26) show that /w/ may be nasalized either intervocalically or after a consonant.

Consider, however, the form in (27), in which /w/ fails to nasalize:[8]

(27) /iYwren/ [iYwũr̃ẽ] 'seven'

(27) shows that if /w/ is part of the labiovelar fricative /Yw/, it is not nasalized. If /Yw/ were simply a sequence of /Y/ plus /w/, analogous to the sequence /Rw/ in (26d), then the [w] would nasalize as it does in the

----

7. /B/ -> [ɥ] / __ [V,-back]. ([ɥ] is a front rounded glide.) [R] is a voiceless trill or tap, in contrast to [r], which is a voiced flap.

8. The vowel between [Yw] and [r] in this example is due to a process inserting a vowel between the labial consonants /B,w,Yw/ and /r/.

sequence /Rw/. We may account for the difference between /Rw/, in which /w/ nasalizes, and /Yw/, in which it doesn't, by analyzing /Rw/ as a two-segment sequence of /R/ followed by /w/, and /Yw/ as a single, labiovelarized fricative represented on a single root node, as in (28a,b).

(28)

```
a.  /Rw/                                            b.  /Yw/
        x                  x                              x
        |                  |                              |
      root               root                           root
        | \                |  \                           |  \
     supra [+cons]     supra  [-cons]               supra [+cont,+cons]
        |                  |                              |
      place              place                          place
        |                  |                             /  \
     coronal             labial                    labial dorsal
      /   \                |                              |
[-ant] [-dist]        [+round]                      [+round]
```

Since in Urhobo nasal harmony, nasalization may link only to [-consonantal] segments, the fact that it links to /w/ in /Rw/ but not in /Yw/ is explained by the structures above. In /Rw/, /w/ is an independent, [-consonantal] segment, to which nasalizatin may link. In /Yw/, a multiply-articulated labiovelar fricative, /w/ is merely one of the articulations in a [+consonantal] segment, and /w/ may not be nasalized because only [-consonantal] segments may be nasalized.

2.3.4 Timing

Another source of evidence for distinguishing between consonant clusters and contour or complex segments is their relative durations. The representation of contour and complex segments on single x-slots makes certain predictions regarding their phonetic durations relative to other consonants (on one x-slot) and to consonant clusters (on two x-slots).

2.3 Clusters vs. Contour or Complex Segments

As discussed above, x-slots encode segmenthood for the purposes of syllabification. However, the x-tier is also a "timing tier," each x representing a unit of phonological timing. Clements (1986), for example, calls it "an abstract tier or level of representation which characterizes phonological <u>timing relations</u>" (p.2) and which "is related in an obvious way to phonetic duration" (p.4).[9] For example, a geminate consonant or vowel consists of a single articulation but has the length of two segments. Geminates are represented as in (29b). They differ from their short counterparts only in the number of timing units their features are associated with ((29a) vs. (29b)).

```
(29)    a.      [ F ]           b.      [ F ]
                  |                      / \
                  x                     x   x
```

Thus, in geminates, the timing units correlate directly with phonetic length.[10] If contour and complex segments are phonologically associated with single timing units, therefore, then we would expect them to have the phonetic length of single consonants, rather than the length of consonant clusters, which occupy two timing units. Preliminary investigations indicate that indeed, contour and complex segments have the phonetic

----

9. See Clements (to appear), McCarthy (1983), and references cited there. Others, e.g. Archangeli (1984), call this tier the "core skeleton" to avoid making claims about its relation to phonetic timing.

10. Note, however, that timing units correlate directly with phonetic length only when other effects on duration (e.g. segment type and environment) are held constant. Thus, vowels are usually longer than consonants, and stressed vowels are longer than unstressed vowels. The point is not that timing units are the only factor determining phonetic length -- they aren't -- but rather that they have a regular acoustic correlate of length, and thus encode timing in addition to segmenthood.

durations of single segments, as is predicted by their representation on single timing units.

2.3.4.1 Prenasalized Stops

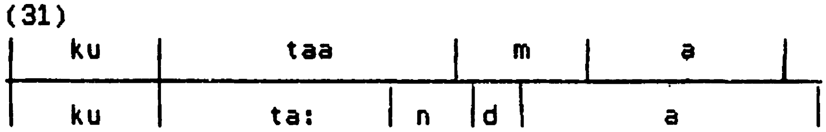
Prenasalized stops are a type of contour segment, i.e. a sequence of articulations represented on a single x-slot, as in (30).

(30)

```
                x
                |
               root
                |
              supra
             /     \
        soft-pal    \
         /   \       place
  [+nasal] [-nasal]
```

Herbert (1975) has investigated the timing of prenasalized stops in Luganda. He finds their length to be "only slightly greater than [that of] units" (p.110). He does not present his results quantitatively, but does give graphs of relative durations like that in (31) (p.113):[11]

(31)



kutaama 'to grow fierce'

kuta:nda 'to betray'

----

11. The extremely short durations of the first syllables in the words in (31) are due to the fact that prefix vowels are "extra short" in Luganda, a phenomenon also reflected in the frequency with which prefix vowels are deleted in Luganda and related languages. See Herbert (1978:152) for discussion.

2.3.4.2 Affricates

An affricate is also represented as a sequence of articulations on a single timing unit, as in (32).

(32)
```
            x
            |
          root
          /  \
   supra  [-cont] [+cont]
     |
   place
```

The length of affricates vs. stop-fricative clusters in Polish has been investigated by Brooks (1965). Brooks shows "on acoustic grounds that [contrary to Bloomfield's (1956) assertion] the phonetic distinction between [č] ... and [tš] in Polish cannot be discussed in terms of the occurrence of close and open transitions" (p.207). Rather, Polish /ć,č,ǯ/, which are "unit affricates functioning as unit phonemes," are "produced with close transition," while /ts,tš,dž/, which are "sequential affricates consisting of two consonantal phonemes" and sometimes but not always separated by a word boundary, are "produced with either closed or open transition" (p.209).[12] In my terms, /ć,č,ǯ/ each occupy a single x-slot, while /ts,tš,dž/ each occupy two x-slots (which explains why only the latter may be separated by a word boundary). Brooks concludes that "the relative length of [š] was found to be the only consistent element of distinction between [tš] and [č]" (p.209). That is, the only distinction

----

12. Brooks does not investigate the durations of [ǯ] and [dz] because [dz] occurs only at morpheme boundaries (p.210).

between the clusters and the contour segments is that the clusters consistently have a longer fricative portion than the affricates do. Brooks' results are given in (33) (= Brooks' Table 2, p.209).

(33) Total Average Lengths of [č] and [tš] (in seconds)

Informant	Initially		Medially		Finally	
	č	tš	č	tš	č	tš
SM	0.17	0.24	0.13	0.20	0.15	0.17
JG	0.18	0.24	0.14	0.21	0.19	0.23

The contrasts in (33) occur in minimal pairs such as:

(34)	[č]:	czy	'whether'	[tš]:	trzy	'three'
		Czech	'Czech'		trzech	'of three'
		dzyj	'whose'		trzyi	'rub'

In Sagey (to appear), I report on the results of an experiment comparing the length of affricates in English to that of English stops, fricatives, and stop-fricative clusters. I show that the affricates [č,ǰ] are significantly shorter than the stop-fricative clusters [gz, ks, ts, ps, pš] in English. While all consonants are shortened to some extent in clusters (in my data the consonants in stop-fricative clusters are shortened to between 90 and 98 percent of their durations in VCV context), the affricates [ǰ] and [č] are far shorter than the effects of shortening in clusters alone could explain. The durations of [ǰ] and [č] are 62 and 69 percent, respectively, of the sum of the durations in VCV context of [d] and [ž] and of [t] and [š], respectively. The average durations obtained for [t,d,š,ž,č,ǰ] are given in (35).

(35)	d	88	t	91
	ž	125	š	139
	ǰ	133	č	159

If [ǯ] and [č] were two-segment clusters of stop plus fricative, we would expect their durations to be around 192 ms. and 207 ms., respectively (because that would be 90 percent of the sums of the durations of [d] and [ž] and of [t] and [š], respectively).

Finally, Kuipers (1960) reports that in Kabardian there is a length distinction between the affricate [ʒ] and the sequence of two segments [dz]. For example, the difference between [ʒas] 'it has been thrown' and [dzas] 'we have filtered it' is that "in the latter word the dental friction is of a markedly longer duration."[13]

2.3.4.3 Labiovelars

There have been experiments showing that complex segments, like contour segments, have the durations of single x-slots. This is to be expected, given the representation of complex segments on single x-slots as in (36):

(36)

```
            x
            |
          root
            |
          supra
            |
          place
          /   \
     labial    \
             dorsal
```

----

13. Kuipers notes that "in the sequences ts, dz (as opposed to ȼ,ʒ) there is always a morpheme border between the two consonants" (p.20). This need not be evidence against a structural difference between the affricate and the cluster; more probably, the structural difference arises because of the morpheme boundary.

For example, Garnes (1975) presents an acoustic analysis of the doubly-articulated plosive [kp] in the Nigerian language Ibibio.[14] She compares voiceless [kp,k] and voiced [b], as in the words [akpa] 'the open sea' and [aka] and [abak], both names of towns. She finds that

> although in phonation and voice onset time the three types of plosives differ, there are similarities. The duration from the end of the first vowel to the onset of the second vowel is nearly identical for the double articulated and voiceless velar plosives. The total vowel to vowel duration is 261 ms. in the words with [kp] versus a total of 249 ms. in the words with [k] ... This similarity indicates that the two types of plosives are programmed similarly and provides evidence that the double articulation constitutes a single unit of timing (p.48).

Ibibio has no consonant clusters against which to compare the duration of [kp].

Maddieson (1983) gives waveforms illustrating the durations of intervocalic /kp/, /k/, and /t/ for a speaker of Yoruba. He states that "all the Yoruba closures are of approximately equal duration (about 130 msec.) regardless of whether they have single or double articulation" (p.296).

In addition, preliminary investigation shows that Igbo labiovelar [gb] also has the duration of a single segment. The Igbo words in (37), which I recorded for one speaker, had the durations given in (37) (measured on Specto spectrograms to the nearest 5 msec.):

(37)	agadi	'elderly person'	[g]	90 msec.
	iba	'malaria'	[b]	110 msec.
	agba	'jaw'	[gb]	112 msec.

----

14. [kp] in Ibibio is an allophone of /p/ in certain environments.

The duration of the complex segment [gb] (112 msec.) is virtually the same as that for [b] (110 msec.). Igbo has no consonant clusters against which to compare the complex segments, but based on the data in (37), we may conclude that the phonetic durations of Igbo complex segments support their phonological representation on single timing units.

2.3.5 Reduplication and Association to the Skeleton

As I discussed in Chapter 1, association to the skeleton in root-and-pattern morphology and in reduplication provides evidence for certain sounds behaving as single melodic segments, i.e. on single root nodes. Such data also descriminates between consonant clusters, on two x-slots, and contour or complex segments, on single x-slots. If a segment is on a single root node, then, unless it's a geminate, it must also be on a single x-slot. The model of reduplication I assume is that outlined in Chapter One, following Marantz (1982).

Reduplication in Ewe, described by Ansre (1963), provides clear evidence that the labiovelars, affricates, and palatalized segments in Ewe are on single root nodes. Ewe verb stems may be of the forms: CV, CLV, and CiV, which reduplicate as: CVCV, CVCLC, and CVCiV, respectively. That is, clusters of consonants and vowels do not reduplicate together. However, the data in (38) show that palatalized /ny/, labiovelar /kp,gb/, and the affricate /ȼ/ are all preserved in reduplication, not split up as are the clusters CL and Ci. Therefore, /ny,kp,gb,ȼ/ must be single segments.

(38) Verb --> present participle (with /-m/), adjective, or noun:

(CV)	fo	'to beat'	fofo	'beating'
	zo	'to walk'	zozom	'walking'
	aha + no	'liquor + to drink'	ahanono	'liquor drinking'
	ɛ́i	'to grow'	ɛ́iɛ́ii	'grown up'
(CiV)	fia	'to burn'	fafiaa	'burnt'
	bia	'to ask'	babiam	'asking'
	avo + sia	'cloth + to dry'	avosasia	'cloth drying'
(CLV)	fle	'to buy'	feflee	'bought'
	kplo	'to lead'	kpokplo	'leading'
	gbla	'to exert oneself'	gbagblam	'exerting oneself'
	nyra	'to rave'	nyanyrala	'a raver'

In Alagwa (described by Tucker and Bryan (1966:575)), the plural of a noun is formed by suffixing /aCu/ and spreading the root node of the final consonant onto the suffixed onset slot, as shown by the data in (39):

(39) kebi kebabu 'cooking stone(s)'
iliba ilibabu 'milk(s)'

```
k e b                          k e b
| | |                          | | |\
x x x - x x x        ==>       x x x x x x
        |   |                        |   |
        a   u                        a   u
```

This spreading treats labiovelar /kw/ as a single segment, as shown by the form in (40):

(40) yakwa yakwaku 'calabash(es)'[15]

Thus, /kw/ must be represented on a single root node, as in (41), in order for both /k/ and /w/ to spread.

----

15. [yakwaku] is derived from /yakwakwu/ by deletion of [w] before [u].

(41)
```
          root
           |
          supra
           |
          place
          /   \
     labial    \
             dorsal
```

If /kw/ were not represented as in (41), but instead were represented on two root nodes, then the spreading process would spread just /w/ alone, yielding *yakwawu, which doesn't occur.

That this would be the result if /kw/ were two root nodes is shown by a similar process in Hausa, in which /ny/ is a cluster, with two root nodes, rather than a complex segment. In Hausa, the plural is formed by suffixing /ooCii/ and spreading the root node of the final consonant onto the suffixed onset slot (data from Gregersen (1967)):

(42)	zaakii	'lion'	zakookii	'lions'

However, unlike /kw/ in Alagwa, /ny/ in Hausa behaves as a cluster. Only /y/ spreads:

(43)	hanyaa	'road'	hanyooyii	'roads'

Thus, /ny/ in Hausa must be represented on two root nodes (and by the assumption of no branching class nodes, also on two x-slots), as in (44).

(44)
```
      x        x
      |        |
     root     root
      |        |
    supra    supra
      |        |
    place    place
      |        |
   coronal   dorsal
```

The contrast between Hausa /ny/ and Alagwa /kw/ shows that Alagwa /kw/ must be represented on a single root node.

2.3.6 Lack of Gemination

In Kinyarwanda, as discussed above, there are processes transforming underlying sequences of nasal plus consonant and of consonant plus unsyllabified vowel into prenasalized segments and labiovelarized/ palatalized segments, respectively. Evidence was presented from syllable structure and from compensatory lengthening showing that these processes must result in single segments, i.e. segments represented on one x-slot. Further evidence that these processes result in single segments can be found in cases of prenasalized nasals or labiovelarized velars.

Consider, first, the prenasalization data in (45), from Sibomana (p.111):

(45)	a.	/si-n-dod-a/	[siindoda]	'I don't sew'
		/si-n-mes-a/	[siimesa]	'I don't wash'
	b.	/si-n-a-dod-aga/	[sinadodaga]	'I didn't sew'
		/si-n-a-mes-aga/	[sinamesaga]	'I didn't wash'

The forms in (45b) show that the vowel in /si-/ is underlyingly short, and thus that the length of [ii] in (45a) must be due to compensatory lengthening accompanying the prenasalization. Thus, [siimesa] in (45a) contains a prenasalized /m/, which is realized simply as [m], and not as a geminate [mm]. This provides evidence that the [nd] in [siindoda] is also a single segment, for if prenasalization created two-segment sequences of homorganic nasal followed by a consonant, then we would expect a prenasalized /m/ to result in [mm], not [m]. Of course, it would be possible to derive the correct result under an analysis of prenasalized stops as two-segment clusters, but it would require an additional process of degemination. However, under the analysis of prenasalized stops as single segments, derived by linking [+nasal] to the stop, no degemination process is required. Rather, the fact that a prenasalized nasal is simply a (non-geminate) nasal is predicted.

Since x-slots, and not features, represent the timing of the word, a figure such as (46) can be interpreted only as a segment of unitary length which happens to be redundantly specified for certain features.[16] It cannot be interpreted as a geminate.

```
(46)              [+nasal] [+nasal]
                         \ /
                          x
```

Nor, I maintain, is there any need for a "clean-up" rule of the form in (47).

```
(47)      [a F]   [a F]                [a F]
              \ /              ==>       |
               x                         x
```

Rather, the structure in (46) is itself a well-formed representation for a nasal consonant of unitary length.

Similarly, cases of labiovelarized velars show that the results of

----

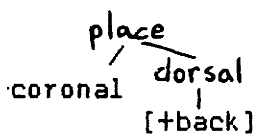
16. In this context, "redundant" specification of features refers to a structure such as (46), in which the value for a certain feature is actually specified twice, or redundantly. I do not refer to the filling in of predictable feature values by redundancy rules.

labiovelarization, [pk], [tkw], etc., must be single segments. Consider the data in (48).

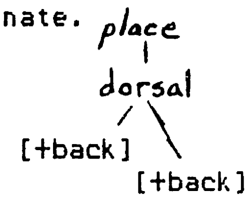
(48)	a.	/ubu-oko/	[ubgooko]	'race'
	b.	/umu-ana/	[umŋaana]	'child'
	c.	/tu-ese/	[tkweese]	'all of us'
	d.	/tu-anga/	[tkwaaŋga]	'we hate'
	e.	/ku-ič-w-a/	[kwiičwa]	'to be killed'
	f.	/ku-ak-w-a/	[kwaakwa]	'to be asked'

In (48a-d), if labiovelarized [bg], [mŋ], and [tkw] were multi-segmental sequences of which the second consonant were a velar, then we would expect labiovelarized underlying /k/ to be also a sequence of segments, [k] plus [k], i.e. resulting in *kkwaakkwa instead of [kwaakwa] in (48f), and in *kkwiičwa instead of [kwiičwa] in (48e). That the result of labiovelarizing a velar is not a geminate velar shows that the labiovelarized complex onsets in (48a-d) must be single segments, derived by linking [+back] to the consonant, as in (49a). In (49b) is shown the result of velarizing a velar -- a single segment that is redundantly specified as [+back], not a geminate.

(49) a.



b.



2.3.7 Dan (Santa)

In Dan (Santa) there is a contrast between labialized consonants (on one x-slot) and sequences of consonant plus /w/ (on two x-slots). Dan (Santa) has extensive palatalization and labialization of consonants, but most of these are best analyzed as Cw and Cy clusters in which the /w/ and the /y/ occupy their own x-slots. Only /kw/ and /gw/ are underlyingly represented on single x-slots. Thus, the representation of the Cw and Cy clusters is as in (50a), while the representation of /kw,gw/ is as in (50b).

```
(50)
a.      x        x               b.      x
        |        |                       |
       root     root                    root
        |        |                       |
       supra    supra                   supra
        |        |                       |
       place    place                   place
        |        |                      /  \
 (articulator)   |                  labial  \
               labial                       dorsal
              or dorsal
```

Evidence for the structural distinction in (50) is that in a labialized or palatalized consonant, according to Bearth and Zemp (1967), "by auditory judgment, the segment following C may sometimes -- except in the sequences /kw/ and /gw/ -- be identified as a vowel-like sound, sometimes as a labializing or palatalizing modification of the initial consonant" (p.15). If we assume that the underlying representations of Cw, Cy, and /kw,gw/ are as in (50), then we may account for the difference noted by Bearth and Zemp as follows. In (50a), the labial or dorsal glide may be realized as a vowel, or it may be merged with the preceding consonant and realized only as a modification of the consonant. In (50b), on the other hand, there is no possibility of /w/ being pronounced as a vowel because it is underlyingly just a labial modification of /k/ or /g/.

Another distinction between /kw,gw/ and the other labialized and palatalized consonants is the following: "Phonemic length is realized differently according to the type of syllable-initial consonant. If the syllable-initial consonant is unmodified, or /kw/ and /gw/, the vowel is lengthened, [whereas] after all labialized and palatalized consonants, except /kw/ and /gw/, lengthening of the vowel fluctuates with 'vocalization', i.e. lengthening of the pre-nuclear margin" (p.21). A /w/ on its own x-slot may "vocalize", whereas /w/ on the same x-slot with a consonant may not. Examples are given in (51), in which I ignore structure within the root node:

(51) a. Cy cluster: /bye:/ [bye:] ~ [bie] 'cord'

```
     σ                       σ
    / \                     / \
   O   R                   O   R
   |  / \                  |  / \
   x  x  x        ~        x  x  x
   |  |  |                 |\  \ |
   b  i  e                 b i   e
```

b. labialized k: /kwe:/ [kwe:] 'loom'

```
     σ
    / \
   O   R
   |  / \
   x  x  x
   |\  \ |
   k w   e
```

2.4 Contour vs. Complex Segments -- Ordered vs. Unordered

The evidence presented in the previous section proves that certain segments are represented on single x-slots. In this section, I will distinguish between two types of segments with multiple articulations on single x-slots: contour segments, in which the articulations are phonologically in sequence, and complex segments, in which the articulations are not in sequence. While both contour and complex segments are represented on single x-slots and thus share certain properties with respect to syllabification, compensatory lengthening, and reduplication, there is a crucial difference between them: the multiple articulations in a contour segment are phonologically ordered; the multiple articulations in a complex segment, while they may be pronounced in a phonetic order, are phonologically unordered. This difference affects the way contour and complex segments behave with respect to rules of phonology.

2.4.1 Contour Segments

First, I establish that the two articulations in a contour segment -- e.g. affricate or prenasalized stop -- are phonologically ordered, based on their behavior with respect to phonological processes in the languages they occur in.

Affricates are made up of sequences of two articulations: stop + fricative. They behave as stops with respect to phonological rules sensitive to their left edges. For example, there is a rule in Zoque which voices a non-continuant after a nasal:

(52) Zoque: [-cont] --> [+voice] / [+nasal] _____

The rule in (52) applies to both stops and affricates, as noted by Kenstowicz and Kisseberth (1979:35), and as shown by the data in (53) (Wonderly (1951:120)):

(53)	/min - pa/	[minba]	'he comes'
	/min - tam/	[mindam^]	'come! (pl.)'
	/p^n - č^ki/	[pʌnǰʌki]	'figure of a man'
	/p^n - kʌsi/	[pʌngʌsi]	'on a man'

/N - pama/	[mbama]	'my clothing'
/N - tatah/	[ndatah]	'my father'
/N - čo?ngoya/	[ñǰo?ngoya]	'my rabbit'
/N - kayu/	[ŋgayu]	'my horse'

In contrast, sequences of nasal and fricative are either left unaffected, or the nasal is deleted.

(54)		[winsa?u]	'he received'	(112)
		[?aŋsis]	'lips'	(112)
		[wo?msoŋ]	'quail'	(114)
	/N - sʌk/	[sʌk]	'my beans'	(121)
	/N - šapun/	[šapun]	'my soap'	(121)

The data in (53,54) is explained by the representation of affricates as branching for the feature continuant, as in (55b). Since the voicing rule is sensitive to a nasal followed by a [-cont], the fact that voicing applies in (55a,b) but not in (55c) is entirely predicted.

(55)

```
a.  stop               b.  affricate              c.  fricative

   x    x                   x       x                   x    x
   |    |                   |       |                   |    |
 root root                root    root                root root
   |    |                   |      / \                  |    |
 supra  |                 supra   /   \               supra  |
   |  [-cont]               |  [-cont][+cont]           |  [+cont]
soft-pal                 soft-pal                    soft-pal
   |                        |                           |
[+nasal]                 [+nasal]                    [+nasal]
```

On the other hand, affricates behave as fricatives with respect to phonological rules sensitive to their right edges. One example of such a rule is the English plural rule inserting schwa between strident fricatives and the plural /-s/, which inserts schwa after both fricatives and affricates. Another rule sensitive to the right edge and which treats affricates as fricatives is labialization in Kutep, where the result of labialization is a labiodental after fricatives and affricates, in contrast to a bilabial after stops (Ladefoged (1968:31,62)).

(56)	fricatives	basfa	'they kneel'
		nsazvakkwa	'the water is hot'
		baẑve	'they washed'
		baẑvam	'they begged'
		açfapaŋ	'groundnuts'
	affricates	baćfap	'they chose'
		batçfak	'they sleep'
	stops	bapwa	'they grind'
		bambwa	'they tasted'
		batwap	'they picked up'
		bandwap	'they wove'
		nsazvakkwa	'the water is hot'
		baŋgwa	'they drink'
		baskwap	'they are foolish'

Finally, in Sierra Popoluca, stops are aspirated at the end of a syllable, while affricates and fricatives are not (Foster and Foster (1948)).

(57)

stops	/hɂp/	[hɂph]	'mouth'	
	/?ampat/	[?ampath]	'I met'	
	/mɂk/	[mɂkh]	'fog'	
affric.	/mać/	[mać]	'grasp'	(*maćh)
	/?apič/	[?apič]	'thorn'	(*?apičh)
fric.	/wɂsten/	[wɂsten]	'two'	(*wɂshten)
	/pištɂk/	[pištɂk]	'flea'	(*pishtɂk)

If this rule is stated as applying to a [-cont] at the end of a syllable, as in (58), then it will automatically fail to apply to affricates, which, although they contain a specification [-cont], are phonologically [+cont] on their right edge, to which the rule is sensitive.

```
(58)            x       ]
                |      σ
               root
laryngeal       |
    |         [-cont]
[+spread gl]
```

For these reasons, autosegmental phonology represents affricates as sequences of two elements on the feature tier, although they are single elements on the timing tier:

```
(59)            x
                |
              root
              /  \
        [-cont] [+cont]
```

Like affricates, prenasalized stops consist of sequences of articulations: nasal + non-nasal, represented as in (60).

```
(60)            x
                |
               root
                |
              supra
                |
             soft-pal
              /   \
        [+nasal] [-nasal]
```

Prenasalized stops behave phonologically as nasals with respect to segments preceding them, and as non-nasals with respect to segments following them, as evidenced by the distribution of pre- and post-nasalized consonants and nasal vs. oral vowels in Kaingang (noted by Herbert (1975:107)):

```
(61)    n   /  Ṽ __ Ṽ
        nd  /  Ṽ __ V
        dn  /  V __ Ṽ
        dnd /  V __ V
```

Another case where a prenasalized stop behaves as non-nasal with respect to a phonological rule sensitive to its right edge is in Land Dayak, where vowels are nasalized after nasal consonants (possibly separated by glottal stop) (Kenstowicz and Kisseberth (1979:146-148)):

```
(62)     root      root                         root      root
           |         | \                          |         | \
         supra    supra \           ==>         supra    supra \
           |              [-cons]                 |         |    [-cons]
      soft-pal                                soft-pal  soft-pal
           |   ↗                                    \    /
        [+nasal]                                   [+nasal]
```

The process in (62) is not blocked by an intervening glottal stop because a glottal stop has no supralaryngeal node. See Chapter 1 for arguments for "interpolating" the soft palate node in (62).

The rule in (62) does not apply after prenasalized stops. Instead, the distribution of nasalized vowels that results is that shown in (63) -- nasalized vowels after simple nasal consonants in column one, vs. oral vowels after prenasalized stops in column two:

(63)	mãlu	'strike'	sampE:	'extending to'
	nãbur	'sow'	suntOk	'in need of'
	ənãk	'child'	suŋkoi	'cooked rice'

This distribution of nasalization is explained by prenasalized stops being [-nasal] on the right edge, as shown in (60).

As demonstrated by Kenstowicz and Kisseberth, the vowel nasalization process in (62) must apply at a relatively abstract, phonological level. Thus, it provides evidence for the phonological representation of prenasalized stops as in (60). That is, (60) is not merely a representation of the phonetic realization of a prenasalized stop, but is the actual phonological representation. Vowel nasalization must be phonological in Land Dayak because it is sensitive not to the phonetic representation, or pronunciation, of the prenasalized stop, but to its phonological representation. In Land Dayak, underlying voiced prenasalized stops surface phonetically as simple nasals; nevertheless, they behave as [-nasal] with respect to the nasalization of the following vowel. Thus, nasalization must apply at a relatively abstract, phonological, level, prior to simplification of voiced prenasalized stops.

(64)	Nas.		Simplif.				
/əmbun/	===>	əmbun	===>	əmun	==>	[əmudn]	'dew'
/məndam/	===>	mə̃ndam	===>	mə̃nam	==>	[mə̃nabm]	'sickness'

The last step in (64) is a process which derives phonetic postnasalized stops from phonological nasals word-finally after an oral vowel. These postnasalized stops, unlike the prenasalized stops, do not occur underlyingly in Land Dayak.

(65)	/pəlam/	[pəlabm]	'mango'
	/ntakan/	[ntakadn]	'taste'
	/padaŋ/	[padagŋ]	'field'

Thus, the phonological behavior of prenasalized stops, like that of affricates, provides evidence for their representation as in (66) -- sequences of two elements on the feature tier, although single elements on the timing tier.

```
(66)          x
              |
             root
              |
            supra
              |
         soft-palate
            /   \
      [+nasal] [-nasal]
```

2.4 Contour vs. Complex Segments -- Ordered vs. Unordered

The data presented in this section show that phonological rules applying on level where contour segments are branching will apply to the adjacent part of the contour: e.g. an affricate will behave as [-cont] with respect to rules on the left and as [+cont] with respect to rules on the right; and prenasalized stops will behave as [+nasal] on the left and as [-nasal] on the right. This phonological behavior is evidence for the two articulations in a contour segment being phonologically ordered, and represented as in (57) and (66).

2.4.2 Complex Segments

Unlike contour segments, complex segments involve articulations which are not phonologically ordered. Even where phonetically the articulations may be (or seem to be) ordered, phonologically they are unordered. A complex segment such as labiovelar [kp] will behave phonologically as both labial and velar with respect to processes both on the left and on the right.

I show in this section that not only must a complex segment be represented on a single x-slot and root node in order to capture its behavior with respect to syllabification, reduplication, association to the skeleton, and timing; but also, complex segments differ from contour segments in that their multiple articulations are phonologically unordered, and must be represented within a single place node constituent. That is, they must be represented as in (67a), and not as in (67b,c,d):

(67)

```
 a.     x           b. *    x          c. *  x          d. *      x
        |                   |                |                   / \
       root                root             root            root  root
        |                   |                / \              |     |
       supra              supra         supra supra         supra supra
        |                  / \            |     !             |     |
       place         place place      place place         place place
       /   \            |     |          |     |             |     |
  dorsal  labial   dorsal labial    dorsal labial        dorsal  labial
```

The ill-formedness of (67b,c,d) has already been argued for on the basis of disallowing branching class nodes within a segment. However, I will argue below that there are further reasons to assume the structure in (67a) over those in (67b,c,d).

2.4.2.1 Nasal Assimilation and Prenasalization

For example, preceding nasals will assimilate to both the labial and the velar articulations of /kp/. This can be seen in the nasal assimilation data from Kpelle given in Chapter 1, repeated below, in which tone-bearing nasals assimilate in place of articulation (Welmers 1962), and /n/ is doubly articulated in velar and bilabial positions before /kp/, providing further evidence for a place node uniting labial and velar articulators (p.79).:

(68)	/N-polu/	[ḿbolu]	'my back'
	/N-tia/	[ńdia]	'my taboo'
	/N-kOO/	[ŋ́gOO]	'my foot'
	/N-kpiŋ/	[ḿŋgbiŋ]	'myself'
	/N-fela/	[ḿvela]	'my wages'
	/N-sua/	[ńʒua]	'my nose'

Given that labiovelar /kp/ is represented on a single x-slot, and therefore with unordered labial and velar articulations under the place node, nasal assimilation must assimilate both the labial and the velar articulations, as shown in (69):

```
(69)    supra    supra                      supra    supra
         /                                   /      \   /
        /          place         ==>        /       place
   soft-pal       /   \             soft-pal        /   \
      |      labial    \                |      labial    \
   [+nasal]          dorsal          [+nasal]          dorsal
```

Given the representation of /kp/ in (69), there would be no way for place assimilation spreading the place node to spread just the dorsal, or just the labial, articulation.

In Yoruba, also, nasal assimilation provides evidence that the two articulations in a labiovelar segment in that language are both contained under a single place node. In Yoruba, a syllabic and tone-bearing /m/, which is therefore on its own x-slot, assimilates in place of articulation to a following consonant or /o/ (Bamgbose (1969)):

(70)	m -->	m	/ __ b,m
		ɱ	/ __ f
		n	/ __ t,d,s,r,l,š,ǰ
		ɲ	/ __ y
		ŋ	/ __ k,g,w,h,o

When the following consonant is a labiovelar, the /m/ assimilates to both places of articulation, becoming [ŋm]:

m --> ŋm / __ kp, gb

Examples are:

(71)	a.	/mo m̄ bo/	[mo m bo]	'I am coming'
	b.	/o m fo/	[o ɱ fo]	'he is jumping'
	c.	/o m lo/	[o n lo]	'he is going'
	d.	/o m jo/	[o ɲ jo]	'he is rejoicing'
	e.	/o m ke/	[o ŋ ke]	'he is crying'
		/m o lo/	[ŋ o lo]	'I did not go'
	f.	/o m gbo/	[o ŋm gbo]	'he is hearing'

In the same manner, in Dan (Santa), a syllabic nasal assimilates to the place of articulation of a following consonant, including labiovelars, as shown in (72, 73)) (Bearth and Zemp p.19):[17]

(72)	N -->	m	/ ___ labial
		n	/ ___ alveolar
		ɲ	/ ___ y
		ŋ	/ ___ velar or pause
		ŋm	/ ___ labiovelars

(73)	ya N pu	[ya m pu]	'he has tied me'
	N dɔ̀	[n dɔ̀]	'my father'
	N yɤ̃	[ɲ yɤ̃]	'my eyes'
	ya syaN ga	[ya syaŋ ga]	'he has looked at the plant'
	N gbe	[ŋm gbe]	'my arm'

The nasal assimilations in Yoruba, Dan, and Kpelle provide evidence for the multiple articulations in a complex segment being represented under a single place node, because the nasal which becomes [ŋm] in each of these languages is and remains syllabic. Thus, it must be represented on its own x-slot, and in order for it to take on the labiovelar articulation of the following consonant, the features for the labiovelar place of articulation of that consonant must be spread onto it. Thus, in contrast to prenasalized [ŋmgb] which is derived by spreading [+nasal] onto a [gb], the sequence [ŋmgb] with a syllabic nasal must be derived by spreading the place node of [gb] onto the nasal. The fact that both the labial and the dorsal articulations assimilate is evidence for the place of articulation node uniting the independent articulators labial and dorsal. Spreading a single constituent, the place node, spreads both labial and dorsal

----

17. Bearth and Zemp state that the assimilations in (72) occur when the nasal is not preceded by a non-low front vowel, and that "it is not clear whether and to what extent /N/, preceded by front vowels, assimilates to following consonants" (p.19).

articulations.

Consider now what happens when complex segments are prenasalized -- the nasal portion assumes both articulations. This is a necessary result of the representation of complex segments as having two (unordered) articulator nodes under the place node. As argued above, a prenasalized segment contains the sequence [+nasal] [-nasal] under the soft palate node. Combining this representation with the two articulators of a complex segment yields the representation in (74) of a prenasalized complex segment.

(74)

```
                 x
                 |
                root
                 |
                supra
               /    \
        soft-pal     \
         /  \         place
 [+nasal] [-nasal]    /   \
                     /    dorsal
                labial
```

In (74), since the labial and dorsal nodes are unordered, the sequence [+nasal] [-nasal] applies to both of them, resulting in a sequence of a doubly-articulated nasal, followed by a doubly-articulated oral stop.

This happens, for example, in Margi prenasalized labiocoronals, as shown in (75) (Ladefoged (1968:65)):

(75)	mpa	'fight'	nta	'split'	mnptagU	'bush'
	mba	'tie'	ndal	'throw'	mnbda	'surpass'

The prenasalization data in (75) shows that Margi [pt,bd] are both labial and coronal with respect to their left edges, i.e. that the labial and coronal articulator nodes in /pt/ are unordered, so that both labial and coronal characterize the left context of the segment. Evidence that they are also coronal on their right edges exists in a process which raises /ə/ between an alveolar and an /l/. This process applies both after plain alveolars and after labiocoronals, as shown by the data in (76) (from Hoffman (p.19)):

(76) $/\text{ə}/ \rightarrow \text{higher} \; / \left[\begin{array}{l} +\text{coronal} \\ +\text{anterior} \end{array}\right] \_\_\_ \; [+\text{lateral}]$

/dəl/	[dɨl]	'river'
/ptəl/	[ptɨl]	'chief'

These vowel raising data, together with the prenasalization data, thus show that Margi [pt,bd] are phonologically [+coronal] both on the left and on the right, and thus that [pt,bd] cannot be contour segments, but must be complex segments, with unordered coronal and labial articulations, as in (77):

(77)

```
        x
        |
       root
        |
       supra
        |
       place
       /   \
  labial    \
          coronal
```

Similarly, prenasalized labiovelars are always pronounced with labiovelar nasal portions.[18] Some examples of this are given in (78):

----

18. But see discussion in Chapter 6 of postnasalized [gb] in Dan (Santa).

(78)

a.	Tiv	aa mbe	'she suckled'	
		a ndera	'he began'	
		a ŋgohor	'he received'	
		a ŋmgbahom	'he approached'	(Ladefoged p.61)
b.	Sherbro	mbaŋk	'beads'	
		ndO	'where'	
		ŋmgbaŋmgbaŋ	'rib'	(Ladefoged p.47)
c.	Gbeya	mba	'to greet'	
		ndak	'to chase'	
		ŋguti	'to become burnt'	
		ŋmgban	'to uproot'	(Samarin (1966:19)
d.	Gwandara	ɟiŋka	'thatched roof'	
		gboŋmgboro	'steep river bank'	(Matsushita (1972:6))
e.	Sango	mbi	'I'	
		nda	'end'	
		ŋga	'also'	
		ŋmgba	'to remain'	(Samarin (1967))[19]

2.4.2.2 Spreading and "Metathesis"

The unordered character of the articulations in a complex segment is also shown by some cases where they are derived from simple segments. Often, a palatalized or labialized segment with, apparently, a palatal or labial offglide following the segment, will be derived from a preceding front or round vowel. Such derivations show that the palatalization or labialization in the resulting complex segment is actually a phonologically unordered additive articulation on the segment. If it were phonologically ordered after the other articulation, then the derivation of the palatalized or labialized segment would require, not just spreading [-back]

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19. Although Samarin writes the last two as nga and ngba, he states clearly that "the symbols ng and ngb are convenient representations of phonemes which are more accurately represented as ... phonetic [ŋ], i.e. a velar nasal, and [ŋm], i.e. a coarticulated velar-bilabial nasal" (p.32).

or [+round] onto the segment, but also metathesizing the palatal or labial with the other articulation. If, however, we consider the additive articulation to be phonologically unordered, but simply for acoustic or articulatory reasons perceived or articulated as an offglide, then it may be derived straightforwardly by just spreading [-back] or [+round] onto the segment.

Let us consider some concrete examples. First, consider the process of palatalization in Zoque by which a /y/ before a consonant causes palatalization of that consonant to [Cy], with an apparent [y] offglide in some cases. This process is treated by Wonderly (1951:117-119) as metathesis. Examples are given in (79,80,81):[20]

----

20. /c,j/ here symbolize blade-articulated alveopalatal stops, i.e. stops with the same place of articulation as /č,ǰ/ -- [-anterior].

(79)

a.	y - pata	pyata	'his mat'
	y - pyesa	pyesa	'his room'
	y - buro	byuro	'his burro'
	y - faha	fyaha	'his belt'
	y - mula	myula	'his mule'
	y - wakas	wyakas	'his cow'
b.	y - tatah	catah	'his father'
	y - tih	nʌ cihu	'he is arriving'
	y - dura¢ʌhk	nʌ jura¢ʌhku	'it is lasting'
	y - ¢ʌhk	čahku	'he did it'
	y - sʌk	šʌk	'his beans'
	y - swerte	šwerte	'his fortune'
	y - nanah	ňanah	'his mother'
	y - čo?ngoya	čo?ngoya	'his rabbit'
	y - šapun	šapun	'his soap'
c.	y - kama	kyama	'his cornfield'
	y - gayu	gyayu	'his rooster'
d.	y - ?a¢i	?ya¢i	'his older brother'
	y - hayah	hyayah	'her husband'
	y - huy	hyuyu	'he bought it'

(80)

a.	poy - pa	popya	'he runs'
	kuy - mʌy	kumyʌy	'a week hence'
	poy - wa?a	powya?a	'he already ran'
b.	tey - tih	teycih	'right there'
	yʌy - tih	yʌycih	'right here'
	kuy - tʌm	kuycʌm	'avocado (wood + seed)'
	huy - tam	huycamʌ	'buy! (pl.)'
	poy - ¢u?kum	poču?kumu	'he went out'
	kuy - su?¢-moni	kušu?¢moni	'species of tiny mushroom'
	kuy - nʌ? - mʌ	kuňʌ?mʌ	'Coapilla (place name)'
c.	¢ay - kʌsi	¢akyʌsi	'on the vine'
d.	takay - ?ah	taka?ya	'it became bitter'

(81)

a.	Ny - puht	mbyuht	'you went out'
	Ny - burlaȼ^hk	mbyurlaȼ^hku	'you scoffed'
	Ny - wiht	nwyihtu	'you walked'
b.	Ny - tih	nʌmih ñjihu	'you are arriving'
	Ny - ȼiŋ	ñǰiŋu	'you bathed'
c.	Ny - ken	ngyenu	'you looked'
	Ny - gustaȼ^hk	ngyustaȼ^hku	'you enjoyed yourself'
d.	Ny - hayah	nhyayah	'you are the husband'

The data in (79-81a,c,d) show that a labial, dorsal, or laryngeal consonant is palatalized by the addition of a palatal offglide, while the data in (79-81b) show that a coronal is palatalized by becoming [-anterior, +distributed]. We may represent these palatalizations as a spreading of [-back] from the /y/ onto the following consonant, as in (82).

(82)

```
a. labial     x        x         ==>       x        x
              |        |                   |        |
            root     root                root     root
              |        |                   |        |
            supra    supra               supra    supra
              |        |                   |        |
            place    place               place    place
              |        |                   |      /     \
            dorsal   labial            dorsal  dorsal   labial
              |                            \     /
           [-back]                        [-back]

b. coronal    x        x         ==>       x        x
              |        |                   |        |
            root     root                root     root
              |        |                   |        |
            supra    supra               supra    supra
              |        |                   |        |
            place    place               place    place
              |        |                   |      /     \
            dorsal   coronal           dorsal  dorsal   coronal
              |                            \     /
           [-back]                        [-back]
```

```
c.  dorsal      x       x         ==>       x       x
                |       |                   |       |
               root    root                root    root
                |       |                   |       |
               supra   supra               supra   supra
                |       |                   |       |
               place   place               place   place
                |       |                   |       |
               dorsal  dorsal              dorsal  dorsal
                |                             \     /
             [-back]                         [-back]

d.  laryngeal   x       x         ==>       x       x
                |       |                   |       |
               root    root                root    root
                |       |                   |       | \
               supra    |                  supra   supra \
                |     laryng                |       |  laryng
               place                       place   place
                |                           |      /
               dorsal                     dorsal dorsal
                |                            \    /
             [-back]                        [-back]
```

(82a,b,d) are the proper representations for, e.g., /py/, /ky/, and /?y/, respectively. (82c), the palatalized coronal, is not yet correct, however, for it represents [ty], not [c]. What is at work is a process reanalyzing (82c) as a [-anterior] coronal, rather than as a [+anterior] coronal doubly-articulated with a [-back] dorsal glide. This, then, is the common process whereby adding the feature [-back] to a coronal results in the coronal becoming [-anterior]. Within the standard feature matrix representation of place features, this process has always been an anomolous one. For /t/ is already [-back], under this representation, so adding [-back] should have no effect on it at all. However, within the articulator nodes structure I am proposing, this process is completely natural. /t/ is not [-back] normally, nor is it "-dorsal". Rather, it is represented simply by a place node with a coronal node under it. Adding [-back] is not, then, adding a feature already present in /t/.

Furthermore, adding [-back] entails adding a dorsal articulator node to the place node, as shown in (82c). That a fronted dorsal articulation should have an effect on a coronal articulation is natural. What seems to occur is that the coronal and dorsal articulations, because they are so close to each other, are not pronounced as two independent constrictions, but rather fuse to a single, [-anterior] coronal articulation -- halfway between the original coronal articulation and the dorsal articulation.[21] Thus, the fact that adding [-back] entails adding a dorsal articulator explains why adding [-back] to consonants must result in an additional dorsal articulation. This result is unexplained under an analysis where labials and coronals are redundantly [-back], for then adding [-back] has no effect.

If the articulations of [p] and [y] in [py] were considered to be phonologically ordered, then that order would have to be derived by metathesizing [y] and [p], as Wonderly assumes, for the [y] articulation is clearly derived from a preceding morpheme. However, if the [p] and the [y] are considered phonologically unordered in [py], then no metathesis is required, and [py] is derived simply by spreading the [-back] feature of [y] onto the x-slot of [p], as in (82a).

Thus, I analyze the fact that the palatal articulation in [py], [ky], [?y], etc. is perceived as an offglide as simply an acoustic effect of the

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21. In Zoque, where a [-anterior] stop is part of the inventory, the process results in the palatoalveolar stops /c,j/. However, in most languages, which lack [-anterior] coronal stops, the [-anterior] stop derived by palatalization is then affricated by redundancy rules.

transition to the following vowel. The palatal articulations in [py], [?y] are unordered with respect to [p], [?], moreover, in my analysis, in [ky] there is only one articulation -- a [-back] dorsal articulation -- so there is no possibility of a phonological contour segment. Note that the realization of the palatal offglide after dorsals requires that palatalization be a process spreading [-back], as shown in (82), rather than a process spreading the entire dorsal node, as in (83). For if the dorsal node were spread, then the [-back] articulation would be ordered before the original dorsal articulation (by the ordering of the two dorsal nodes), predicting *[yk] rather than [ky].

```
(83)          x        x        ==>         x        x
              |        |                    |        |
            root     root                 root     root
              |        |                    |        |
            supra    supra                supra    supra
              |        |                    |        |
            place    place                place    place
                       |                    |        |
            dorsal   dorsal               dorsal   dorsal
              |                             |
            [-back]                       [-back]
```

There is further evidence that the palatal offglide is a phonetic effect of the transition from the palatalized consonant to the following vowel. Namely, the palatal offglide fails to occur when the following vowel is /i/, as shown by the data in (84):

(84)	kuy - pit	kupit	'with a tree'
	kuy - ?is	ku?is	'of a tree'
	y - kiht	kihtu	'he tore it'
	y - hiti?	hiti?u	'he pulled it'

The disappearance of the palatal offglide before /i/ is automatic under an analysis in which the palatal offglide is nothing more than a transition from a [+high,-back] consonant to the following vowel. Since /i/ is also [+high,-back], there is no transition.

Palatalizations like that in Zoque, where a consonant with a palatal offglide results from palatalization by a <u>preceding</u> high front vowel /i/ or glide /y/, occur in many languages. One such language is Pame, which displays the alternations shown in (85) (data from Gibson (1956:260), Gibson and Bartholomew (1979:313,315)).[22]

(85)
a. labials

ni-mohi?	[nimmyohi?]	'his/her squash'	no-mohi?	[nommohi?]	'my squash'
ri-m?ao?	[rim?yao?]	'his/her months'	ro-m?ao?	[rom?ao?]	'my months'
ni-wot	[niwwyot]	'his/her bark'	no-wot	[nowwot]	'my bark'
ni-bE	[nibbyE]	'his/her bed'	no-bE	[nobbE]	'my bed'

b. coronals

ni-nas	[niŋyas]	'your citrus'	no-nas	[nonnas]	'my citrus'
ki-da?a	[kiggya?a]	'his/her lair'	ko-da?a	[kodda?a]	'my lair'
ri-da?a	[riggya?a]	'his/her lairs'	ro-da?a	[rodda?a]	'my lairs'
ni-t?E?	[niky?E?]	'his/her blanket'	no-t?E?	[not?wE?]	'my blanket'
ni-thE?E	[nikkyhE?E]	'his/her tamale'	no-thE?E	[notthE?E]	'my tamale'

ski-tahan?	[skikyahan?]	'your (sg.) soap (sg.)'
ki-doa	[kigyoa]	'you walk (sg.)'
ki-na	[kiŋya]	'your tongue'
ki-ndEhEdn?	[kiŋgyEhEdn?]	'your money'
ri-nthoi-t	[riŋkhyoiky]	'women'

c. dorsals

či-kao	[čikyao]	'his/her ear'	ȼo-kao	[ȼokkwao]	'my ear'
ni-k?eš	[niky?eš]	'his/her paper'	no-k?weš	[nok?weš]	'my paper'

The palatalizations in (85a,b,c) are derived as in (86a,b,c),

----

22. The gemination in some of these examples is due to an independent process of stem-initial consonant alternation. See Gibson and Bartholomew (1979) for details.

respectively. (The argument given above for Zoque (see (83)) for spreading just [-high] rather than the dorsal node applies to Pame, also.)

(86)

```
a.  labial     x      x          ==>         x       x
               |      |                      |       |
              root   root                   root    root
               |      |                      |       |
              supra  supra                  supra   supra
               |      |                      |       |
              place  place                  place   place
               |      |                      |      /    \
              dorsal labial              dorsal dorsal   labial
               |                              \    /
             [-back]                          [-back]

b.  coronal    x      x          ==>         x       x
               |      |                      |       |
              root   root                   root    root
               |      |                      |       |
              supra  supra                  supra   supra
               |      |                      |       |
              place  place                  place   place
               |      |                      |      /
              dorsal coronal             dorsal dorsal    coronal
               |                              \    /
             [-back]                          [-back]

c.  dorsal     x      x          ==>         x       x
               |      |                      |       |
              root   root                   root    root
               |      |                      |       |
              supra  supra                  supra   supra
               |      |                      |       |
              place  place                  place   place
               |      |                      |       |
              dorsal dorsal                 dorsal  dorsal
               |                               \    /
             [-back]                           [-back]
```

The data with palatalized coronals in (85b) show that in Pame, just as in Zoque, the combination within a segment of discrete coronal and dorsal articulations is disallowed. However, whereas in Zoque a coronal and dorsal combination is resolved by fusion of the two articulations into one [-anterior] coronal articulation, in Pame the combination is resolved by the deletion of the coronal node, as shown in (86b).

The data in (86) show that a consonant will become palatalized with an apparent palatal off-glide following a high front vowel in Pame. I analyze this palatal offglide in Pame as simply a transition between the palatal consonant and the following vowel, just as in Zoque. The palatal articulation in [py] is represented on the unordered dorsal articulator node, so there can be no phonological ordering between the labial and dorsal articulations. In the palatalized dorsals, as well as the palatalized coronals which surface identical to the palatalized dorsals, there is only one articulator -- the dorsal articulator -- which is specified as [-back]. Thus, here, too, there is no possibility of phonological ordering.[23]

The derivation of palatalized [by] with a palatal offglide is predicted not to occur, or at least to require the application of metathesis (a marked rule), if segments such as [by] are considered to be contour segments, with phonologically ordered articulations of labial followed by palatal. Note, also, that the required metathesis process could not be easily stated. Since the /i/ that triggers palatalization and whose features are spread remains before the palatalized segment, in order

----

23. The only way for there to be phonological ordering in a palatalized dorsal would be if there were a sequence of [+back][-back] linked to the dorsal node. However, this would be incorrect in this case since the apparent offglide is derived from a <u>preceding</u> /i/. Therefore, to represent the result of palatalization, [ky], as a sequence of [+back][-back] would require a phonological metathesis from the original order [-back][+back]. Rather, I analyze /k/ before palatalization as unmarked for [back] (i.e. with a bare dorsal node), and palatalization simply adds [-back], as in (86c).

to metathesize the palatal features as required in this analysis we would have to split apart the linked structure created by spreading [-back], as shown in (87) where I assume, for discussion, that the palatal and labial articulations may be ordered.

```
(87)              Pal                          Met
 x       x        ==>   x       x              ==>     x        x
 |       |              |       |                      |        |
root    root           root    root                   root     root
 |       |              |       |                      |        |
supra   supra          supra   supra                  supra    supra
 |       |              |       |                      |        |
place   place          place   place                  place    place
 |       |              |      /    \                  |       /  \
dorsal  labial        dorsal dorsal  labial          dorsal  labial dorsal
                          \   /                        |             |
[-back]                  [-back]                    [-back]       [-back]
```

However, the data in (85) is entirely expected under an analysis which treats the two articulations in, e.g., [by] as phonologically unordered. Once the feature [-back] from [i] has spread onto [b], it may be realized phonetically in either order or simultaneously.

A similar process occurred in the development of Ese?exa from Proto-Takanan, as discussed in Girard (1971:38), who states that "*i in sequences $(C)iCV_{back}$ causes palatalization of the consonant immediately following; *i in sequences $(C)ViCV_{back}$ causes palatalization and becomes absorbed in the palatalization of the following consonant." Girard gives the examples in (88):

(88)

a. labial	*a(?)i-puki	>	apyoxi	'why'
	*iba	>	ibya	'jaguar'
b. coronal	*bizu	>	bičo	'shame'
	*ina	>	iña	'to grasp'
	*e-ina	>	eña	'hair'
	*bita	>	bikya	'sweet'
c. dorsal	*a(?)i-kwana	>	akyana	'things'
	*bikwe	>	bikye	'heavy'

This development may be analyzed in exactly the same manner as the synchronic palatalizations in Zoque and Pame. Note, incidentally, that although in most of the examples of palatalized coronals in (88b), the coronal and dorsal articulations are merged to a single [-anterior] coronal articulation, as in Zoque, there is one example, [bikya] 'sweet', in which the coronal plus dorsal combination is eliminated by deletion of the coronal node, as in Pame.

I have shown above that palatalizations triggered by preceding palatal vowels and glides discussed above have certain properties. In particular, they may result in phonetic offglides, which shows that the palatal articulation must be unordered with respect to the other articulation in the segment. This property holds also of labializations triggered by preceding rounded vowels or glides.

In Margi, for example, there is an optional process of labialization of consonants following the vowel /u/. This labialization is realized phonetically as a "labial offglide". However, the derivation of the labialization makes it clear that this labialization is not merely a /w/ following the consonant, but rather is a rounding throughout the consonant, analogous to the palatalizations discussed above. Examples of labialization are given in (89) (from Hoffman,p.42):

(89)

	/tubi/	[tubi]	~	[tubwi]	'to repent'
	/tumbi/	[tumbi]	~	[tumbwi]	'big belly'
	/ŋwadəg-ubi/	[ŋwadəgubi]	~	[ŋwadəgubwi]	'common vulture'
	/hyi-r-ubi/			[hyir bwi]	(an apology)
	/ali-u-fa/			[alifwa]	'into the farm'
	/muka/	[muka]	~	[mukwa]	'a mute person'
	/u ?i/	[u?i]	~	[u?wi]	'on the ground'

The forms in (89) may be derived by a spreading of [+round] from the preceding /u/, as shown in (90a,b,c) for a labial, a dorsal, and a laryngeal consonant, respectively.[24] To simplify the representation, I omit the dorsal node of /u/ in the structures in (90), which would dominate the features [+high,+back]. It is irrelevant for the process of labialization being illustrated.

(90)

```
a.  labial     x       x          ==>        x       x
               |       |                     |       |
             root    root                  root    root
               |       |                     |       |
             supra   supra                 supra   supra
               |       |                     |       |
             place   place                 place   place
               |       |                     |       |
             labial  labial               labial  labial
                                              \     /
             [+round]                        [+round]

b.  dorsal     x       x          ==>        x       x
               |       |                     |       |
             root    root                  root    root
               |       |                     |       |
             supra   supra                 supra   supra
               |       |                     |       |
             place   place                 place   place
               |       |                     |       |  \
            labial     |                   labial labial \
                     dorsal                   \     /     dorsal
           [+round]                          [+round]
```

----

24. Hoffman cites only the forms in (89), not including any labialized coronals, which I consider merely an accidental gap.

```
c.  laryngeal   x        x          ==>        x        x
                |        |                     |        |
              root     root                  root     root
                |        |                     |        | \
              supra      |                   supra    supra \
                |      laryng                  |        |  laryng
              place                          place    place
                |                              |       /
              labial                       labial   labial
                                               \     /
             [+round]                         [+round]
```

In a labialized dorsal, as in (90b), the labial and dorsal articulations are unordered. No metathesis is required to allow the phonetic pronunciation of the labial portion after the dorsal portion. In the labialized labial in (90a), there is only one articulation -- a rounded labial -- hence there is no possibility of phonological ordering, and the realization of a phonetic rounded offglide after the labial stop requires no metathesis. Finally, in the labialized laryngeal in (90c), the laryngeal and labial articulations are unordered, and may be pronounced phonetically in the order laryngeal - labial without any phonological metathesis.

As with palatalization in Zoque and Pame, this process of labialization in Margi must be a spreading of a terminal feature, [+round], rather than an articulator node, labial. In the palatalization examples, this was required in order to avoid the ordering between the two dorsal nodes that would result from spreading the dorsal node onto a dorsal consonant, as shown in (83) above. Analogously, in the labialization in Margi, spreading the labial node would result in a sequence of labial nodes on a labialized consonant, predicting, e.g., *[wb], as shown in (91), rather than [bw].

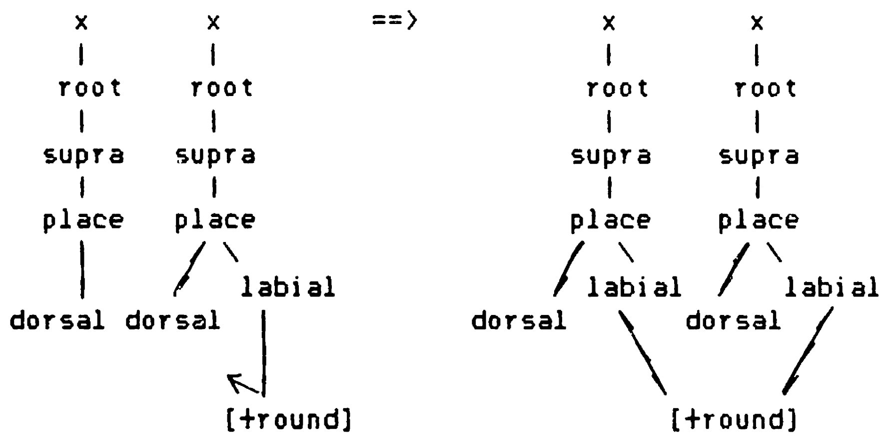
```
(91)        x       x          ==>          x       x
            |       |                       |       |
          root    root                    root    root
            |       |                       |       |
          supra   supra                   supra   supra
            |       |                       |       |
          place   place                   place   place
            |       |                       |      /|
          labial  labial                 labial  labial
            |                               |
          [+round]                       [+round]
```

There is also, in Margi, a process rounding [ə] to [U] before either /w/ or a labialized consonant, as shown in (92) (from Hoffman (p.19,40)):

(92)	/də wudu/	[dU wudu]	'with pregnancy'
	/də wagu/	[dU wagu]	'in the evening'
	/bdəl wa/	[bdUl wa]	'to set (a bone)'
	/də ŋkwa na .../	[dU ŋkwa na ...]	'then that girl ...'
	/anə ŋkwa gəya/	[anU ŋkwa gəya]	'for my daughter'

In (92), the labialized consonant /kw/ triggers rounding on a preceding /ə/, just as a simple /w/ does. The fact that /kw/ is able to spread its rounding to a preceding vowel shows that it is not a contour segment, composed of ordered articulations of /k/ and /w/, but rather is a complex segment with unordered articulations of /k/ and /w/. The derivation of rounding before /kw/ is shown in (93). (In this case, it is not crucial whether the labial node or just [+round] spreads. However, since only [+round] segments, rather than any labial segment, trigger the process, I represent it as a spreading of [+round].)

(93)



Since there is no ordering between the labial and the dorsal articulations in /kw/, it is possible to spread [+round] from /kw/ onto a preceding segment. This shows that the labial offglide in /kw/ is not phonologically ordered after the /k/, which is exactly the result shown by the labialization data in (90), where a consonant is labialized by a preceding rounded vowel. Thus, both the labialization of consonants in (90) and the rounding of vowels in (92) provide phonological evidence for the labialized consonants in Margi not being phonological contour segments. This is further supported by Hoffman's description of labialized consonants in Margi as having "simultaneous lip-rounding" (Hoffman (p.27)).

I have argued in this section that in many cases, palatalization and labialization in consonants should not be represented with phonologically ordered offglides of palatality or labiality. Rather, they should in many cases be considered only to <u>sound</u> <u>like</u> they have offglides, i.e. as a consequence of the transition from the consonant to the vowel. Consider in this regard the following process in Cora (from Campbell 1974:53). In Cora, the (unrounded) labial stops /m,p/ are realized with labial offglides, i.e.

[mw, pw], before the vowel /a/. Thus, in exactly the environment where palatal or labial offglides are most frequently cited in palatalized and labialized consonants (i.e. before the low, non-palatal, non-labial vowel /a/), the simple labial stops /m,p/ in Cora are pronounced with labial offglides. This appears to support the argument that the phonetic pronunciation of an offglide need not entail the phonological representation of a contour segment with [-cons, +round, ...] as the second half. As Garnes (1975) notes, all that is necessary for the perception of an offglide is a slower transition to the following vowel. Garnes (1975) analyzes the formant transitions of labiovelar [kp] in Ibibio. She states:

> It is important to note the duration of the transitions. The transitions following the bilabial and labial-velar occur very rapidly... It might seem that with the greater frequency difference between the hub and steady state following the labial-velar, the duration of the transition would be longer. This does not happen, and indeed, if it did, the resulting perceptual effect would be characteristic of a different <u>manner</u> of articulation -- a glide -- rather than a plosive. The observed rapid transition is essential, and natural for the plosive manner of articulation (p.52).

Another type of evidence that the articulations in a complex segment, and hence the articulator nodes representing those articulations, are unordered comes from a process of labialization in some dialects of Shona in which merger of a velar with a following /w/ results in pre-labial closure (Doke (1931:122)).

(94) <u>Zezuru</u>: kwete <u>Karanga</u>: pkwete "no!"

The realization of the [p] in [pkwete] phonetically before the [k], although it derives from an underlying /w/ following the /k/, does not require metathesis. Rather, when the labiality of the /w/ is added to /k/, it results in a complex segment with unordered labial and dorsal articulations, which may be realized in either order phonetically without requiring phonological metathesis:

(95)

```
          x
          |
        root
          |
        supra
          |
        place
         / \
   dorsal   \
            labial
```

Similarly, the data in (96) illustrate a very common process in Bantu languages by which merger of a labial with a following /w/ results in velar closure before the labial:

(96)

a.	<u>S. Sutho</u>:	roma	'send'	roŋwa	'be sent'
		khomo	'ox'	khoŋwana	'small ox'
		leleme	'tongue'	leleŋwana	'small tongue'
b.	<u>Ronga</u>:	kuma	'find'	kuŋwa/kumiwa	'be found'
		homu	'ox'	hoŋwana	'small ox'
		nomo	'mouth'	noŋwen	(locative)

In (96), the feature [+back] (or equivalently, for these data, the entire dorsal node) spreads from /w/ onto the preceding labial, yielding a structure in as in (95). Since the labial and dorsal nodes are unordered, the realization of the dorsal closure before the labial does not require metathesis.[25]

----

25. On the change in degree of closure of the dorsal and labial articulations, see Chapter 3. On the phonetic ordering between them, see Chapter 6.

2.4 Contour vs. Complex Segments -- Ordered vs. Unordered

In (97) are data from other Shona dialects showing an alternation in the order and in the degree of closure of the labial and dorsal articulations in labiovelar complex segments.

(97)

Kalanga	Lilima	
hapxa	hakhwa	"armpit"
bYe	gwe	"stone"
mbYa	ŋgwa	"dog"
imŋi	iŋwi	"you"

If we assume that the two articulations in a complex segment are phonologically unordered, then such variation in the order in which they are phonetically pronounced is not surprising. The phonetic realization of a labiovelar in one language as a velar followed by a labial and in another as a labial followed by a velar does not require a phonological process of metathesis. Rather, the two languages simply have different processes of phonetic interpretation for complex labiovelar segments. (See Chapter 6 for further discussion of phonetic interpretation and the ordering of the articulations in complex segments.) Thus, although such articulations may be pronounced in a phonetic order, that order will never be distinctive. No language will contrast [pk] and [kp].[26]

Indeed, in some languages there is free variation in the order in

----

26. This conclusion relies on the assumption argued for in Chapter 1 that there may be no branching class nodes in underlying representation. This assumption prevents a distinction between [pk] and [kp] as being, respectively, (i) and (ii) (ignoring structure within the root node):

```
(i)      x                     (ii)     x
        / \                            / \
     root root                      root root
       |    |                         |    |
       p    k                         k    p
```

which the articulations may be pronounced. For example, in Venda, a velarized /m/ may surface as either [ŋw] or [mŋ], as illustrated in (98):

(98) Venda: luma luŋwa/lumŋa "bite/be bitten"

Similarly, among the dialects of Kru, the word for dog has the variants shown in (99):

(99) Kru: bwe ~ gbwe: ~ gbe 'dog' (Westerman and Ward, p.108)

Further evidence for the articulations being phonologically unordered is the fact that often they are pronounced simultaneously, unlike the articulations in a contour segment which must always be pronounced in a particular order. For example, in labialized consonants in Suto-Chuana, the labialization spreads over the entire segment, rather than being pronounced just as an offglide: Westerman and Ward report that "the w-element goes through the whole of the consonant" (p.103).

Thus, the spreadings discussed above of palatality, velarity or labiality over an entire segment, so that each may be pronounced at any point in the "cluster," are not examples of metathesis or of feature copying. They simply result from the lack of phonological ordering between the two articulations, which is predicted by an analysis in which labiovelarization consists of creating a complex (not contour) segment.

Another interesting type of complex segment is that formed from a labial and a palatal. The following data from two mutually intelligible dialects of Yatye show that "where Alifokpa has the labialized palatals **cw**, **jw**, and **njw**, ... Ijiegu has changed the labialized palatals to the palatalized **py**, **by**, and **mby**" (Stahlke (1976:55)).

(100)

Alifokpa	Ijiequ	
icwEndE	ipyEndE	"pot"
ecwu	epyu	"head"
jwu	byu	"drink"
injwi	imbyi	"germinate"

This process occurs synchronically in some dialects of the Sutho group of southern Bantu languages. In these dialects, when a diminutive is formed on a stem which ends in a front vowel, the front vowel palatalizes the preceding consonant. If this consonant is a labial, what results is not a palatalized labial, but a labialized palatal (Herbert 1977:162)).

(101)

Sutho	S. Sutho	Tswana	
lemati	lemačana	lemačana	"door"
ćwhene	ćwheňana	čwheňana	"babboon"
lehofi	lehoćwhana	lexošwana	"palm of hand"
selEpE	selećwana	selEčwana	"axe"
sełopha	sełoćwhana	setłhOčwhana	"troop"

The palatalized forms may be derived as in (102):

(102)

```
a.  coronal    x       x          ==>        x       x
               |       |                     |       |
              root    root                  root    root
               |       |                     |       |
              supra   supra                 supra   supra
               |       |                     |       |
              place   place                 place   place
               |       |                    /  \      |
               |      dorsal               /  dorsal dorsal
             coronal                  coronal     \   /
                     [-back]                    [-back]
```

```
b.  labial     x       x           ==>          x       x
               |       |                        |       |
              root    root                     root    root
               |       |                        |       |
              supra   supra                    supra   supra
               |       |                        |       |
              place   place                    place   place
               |       |                       /  \     |
              labial  dorsal                  /  dorsal dorsal
                       |                 labial     \   /
                     [-back]                       [-back]
```

Although the palatal articulation in (102b) originates in a vowel which follows the labial consonant, once [-back] has linked to the labial consonant, it is unordered with respect to the labial articulation. Thus, it may surface as a palatal consonant preceding the labialization without a phonological metathesis. Actually, Herbert (1977) states that in the palatalized labials in (101), which surface as labialized palatals, "the labiality runs throughout the consonant articulation" (p.162). Whether the labiality represented by [w] is a phonetic offglide following the palatal, or a phonetic labialization throughout the palatal, or both, the conclusion remains the same: the labial and palatal articulations in the segments in (101) are not ordered. In a complex segment, the original order of the segments it was created from is not preserved. (On the degrees of closure of the labial and palatal articulations in the segments in (101), see Chapter 3.)

2.4.2.3 !Xóõ Clicks

The phonology of !Xóõ provides clear evidence that the coronal and dorsal articulations in a click must be phonologically unordered. The processes to be discussed in this section concern the dental clicks shown in (103).

```
(103)   [ǀ]     root                    [ǂ]     root
                 !                               |
                supra                           supra
                 |                               |
                place                           place
                /  \                            /  \
        coronal     \                   coronal     \
         /  \      dorsal                /  \      dorsal
        /  [+ant]                       /  [+ant]
   [-dist]                         [+dist]
```

The coronal articulations in the clicks in (103) are identical to those in the corresponding clicks in Korana and Nama, which I argue in Chapter 3 have the values for [distributed] and [coronal] given in (103).

In !Xóõ, the dental clicks in (103) behave as both coronal and dorsal with respect to phonological processes and restrictions. First of all, there is a process in !Xóõ which raises and fronts the vowel /a/ in certain environments. Traill states that

> the greatest assimilatory effect on /a/ is exerted by the combined effects of a preceding dental consonant such as /t,l,ǂ/ and a following /i,n/. In this environment /a/ is pronounced either as a lowered-high and slightly centralized vowel [ɨ], or as a raised-mid central [ə]. In certain cases it may assimilate fully to the high tongue position of the surrounding consonants and [i] yielding a long [iː]. The presence of /a/ in the succeeding mora is sufficient to block this assimilation even if other conditions for assimilation are present (p.70).

Examples are given in (104):

(104) Dental Assimilation

a. a --> ə,ɨ / dental ___ i,n

b.	/tan/	[tən]	'to it'	(73)
	/ǂali/	[ǂɨli]	'fold Cl. 1'	(70)

2.4 Contour vs. Complex Segments -- Ordered vs. Unordered

The examples in (104) show clearly that the click /ǂ/ in !Xóõ behaves phonologically as a dental with respect to its right edge. This is captured by the representation in (103) where the click has the unordered articulator nodes coronal and dorsal. Since coronal and dorsal are unordered in (103), the click satisfies the environment for Dental Assimilation, which is sensitive to segments which are coronal on their right edge.

Another process in !Xóõ is sensitive to dorsal articulations. This is a morpheme structure constraint requiring that a vowel following a dorsal consonant must be [+back] (/a,o,u/). This "Back Vowel Constraint" applies also to clicks, one of whose articulations is always dorsal, as shown by the representations of /ǀ,ǂ/ in (103), and as argued extensively in Chapter 3. In !Xóõ, most words begin with clicks -- 72.5% of all stems (Traill p.161) -- so most word initial consonants in !Xoo are dorsal. Together with the Back Vowel Constraint, this leads to most initial syllables having a back vowel. In fact, Traill states that 96% of !Xoo words have a back vowel in the first syllable (p.90). The fact that this constraint on syllables beginning with dorsal consonants also applies to the clicks, which include dorsal articulations, shows that clicks in !Xóõ are not sequences of dorsal followed by coronal, but rather must be unordered combinations of dorsal and coronal. Clicks behave phonologically as dorsal with respect to their right edges.

Taken together, Dental Assimilation and the Back Vowel Constraint show that the corono-velar clicks in !Xóõ must be complex segments comprised of unordered coronal and dorsal articulations. The fact that the click /ǂ/

behaves as dental with respect to a phonological process on the right, dental assimilation, shows that it is <u>not</u> a phonological sequence of dental followed by velar. For complexes which are phonological sequences, i.e. the contour segments examined earlier, behave differently with respect to processes on the left or on the right. Similarly, the fact that the click /ǂ/ behaves as dorsal with respect to a phonological process on the right, the Back Vowel Constraint, shows that it is <u>not</u> a phonological sequence of velar followed by dental. The only remaining possibility, given that it is neither a dental-velar contour segment nor a velar-dental contour segment, is that it is a complex segment made up of unordered dental and velar articulations, represented by coronal and dorsal nodes as in (103).

An interesting class of apparent exceptions to the Back Vowel Constraint arises as a result of the application of both the Back Vowel Constraint (which is sensitive to dorsals) and Dental Assimilation (which is sensitive to dentals) in words with the dental clicks /|,ǂ/, which, as argued above, combine both dorsal and dental articulations. These exceptions are listed in (105) (from Traill p.91):

(105)

|?i -i	'lover'	|?a -ba te	(pl.)
|qhi -i	'buffalo'	|ha -ba te	(pl.)
ǂi -i	'steenbuck'	ǂa -ba te	(pl.)
ǂ?i -i	'shoot it! (cl.1)'	ǂ?a -a sa	nominaliz.
ǂqhi -i	'dog'	ǂha -ba te	(pl.)
ǂqhe -e	'sp. bush (term. ser.)'	ǂqha-m	

As Traill notes, the alternations in (105) show that the vowels of the stems in (105) do not violate the Back Vowel Constraint underlyingly, for they surface as /a/ in the plural or nominalized forms in the second column. Rather, in the first column, "the vowel of the stem in the singular has assimilated completely to the Class 1 noun suffix /-i/" (Traill p.91). That is, the assimilation of /a/ to [i] in (105) is just an extreme form of Dental Assimilation, (104). Thus, the only surface exceptions to the Back Vowel Constraint are those with the properties in (105): the consonant is a dental click (not a labial, lateral or alveolar one), i.e. dental in addition to dorsal; and the underlying back vowel following the click is /a/, not /o/ or /u/, because only /a/ is subject to Dental Assimilation. There are a few non-alternating exceptions to the Back Vowel Constraint, but all of these have the "same phonetic shape as the examples in (105), namely a /ǂ/ or /|/ series click followed by a long front vowel, [and thus] have probably arisen by the same assimilatory process that gave rise to the singular forms in (105)" (p.91). One example of this type is the copulative or stative morpheme /|ii/ 'be'.[27]

Another piece of evidence against clicks in !Xóõ being sequences of velar followed by coronal is that the first person singular pronoun /ń-/, as well as the verbal formative /-ń-/, assimilate to the coronal articulation of the click. Traill concludes, and I agree, that it is "necessary to specify clicks simultaneously but independently for an anterior and velar closure" (p.122).

----

27. The only exceptions to the Back Vowel Constraint not containing dental clicks are the forms /ki/ and /ke/ of the grammatical particle /kV/, derived by filling in the vowel /i/ for Class 1 and /e/ for Class 3. Traill notes, however, that "the [Back Vowel] constraint is so powerful that even /ki/ and /ke/ may be subjected to it to yield a frequently heard alternative pronunciation /ti/ and /te/. This reinterpretation of sequences that violate [the Back Vowel Constraint] can also be seen in some recent loan vocabulary where the Afrikaans words <u>baadjie</u> [bajci] 'jacket' and <u>donkie</u> [dOŋki] 'donkey' are incorporated into !Xóõ as /baati/ and /tonti/ respectively. The constraint is therefore productive" (p.90).

2.5 Phonological Processes Applying to Articulator Nodes

Phonological evidence from the spreading of constituents for the articulator nodes in the feature hierarchy is difficult to come by. In the majority of languages, segments involving two or more articulators under the place node are disallowed. In these languages, any segment will have only one articulator node under the place node, in which case spreading the articulator node will be indistinguishable from spreading the entire place node in terms of which features are spread. (Other factors, such as blocking effects in long distance assimilations, may nevertheless provide evidence for the spreading of an articulator in such languages, as shown by Steriade's analysis of Sanskrit retroflex assimilation, discussed in the following section.) On the other hand, in languages where complex segments are allowed, syllable structure tends to be very restricted (often CV), so that assimilations between consonants do not occur. Low-level coarticulations with vowels are not usually remarked upon, just as the rounding of English consonants before /u/ is seldom discussed. What would also demonstrate the constituency of articulator nodes would be cases of segments with two articulator nodes, i.e. complex segments, where only one of the articulator nodes spreads. There would also in such a case need to be more than one feature under the node that spreads, or it would be indistinguishable from spreading a single feature. I know of no such cases, however.

2.5 Phonological Processes Applying to Articulator Nodes

In the following sections, I discuss phonological processes in various languages which I analyze as spreadings or deletions of articulator nodes. Since many of these examples are drawn from languages which do not allow complex segments, they provide independent justification for the articulator nodes structure as a universal property of phonological representations, and not a property confined to the representations of complex segment languages.

2.5.1 Coronal Articulator Node

2.5.1.1 Sanskrit N-Retroflexion

Steriade (1986) analyzes an assimilation in Sanskrit which has the necessary properties to provide evidence for an articulator node, in this case, the coronal node. The crucial properties of this assimilation are that it spreads more than one feature (so it cannot be characterized as spreading a terminal node), that the features it spreads are only those under the coronal node, and that it spreads these features across intervening segments, blocked only by coronals (so it cannot be characterized as spreading the place node).

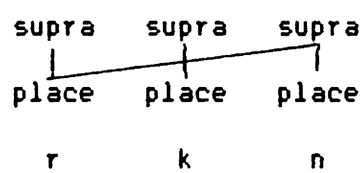
The evidence from Sanskrit in favor of the coronal node as a constituent in phonological processes of spreading is as follows. In Sanskrit n-Retroflexion are found long-distance spreadings of [anterior] and [distributed], by which /n/ becomes [ṇ] after /ṣ/ or /r/, as long as no coronal sound intervenes. Data (from Steriade and Schein (to appear:39) is given in (106).

(106)

		Applies		Blocked	
-na-	'present'	iṣ-ṇa-	'seek'		
		pr-ṇa-		mrd-na-	
-na-	'passive participle'	pur-ṇa-	'fill'	bhug-na-	'bend'
		vrk-ṇa-	'cut up'		
-ana-	'middle participle'	pur-aṇa-	'fill'	marj-ana-	'wipe'
		kṣubh-aṇa-	'quake'	kṣved-ana-	'hum'
		cakṣ-aṇa-	'see'		
-mana-	'middle participle'	krp-a-maṇa-	'lament'	krt-a-mana-	'cut'

First, the data in (106) show that n-Retroflexion is not blocked by intervening vowels (pur-aṇa), labials (krp-a-maṇa-), or dorsals (vrk-ṇa-). Thus, it cannot be a spreading of the place node, for vowels, labials, and dorsals all have place nodes that would block such a spreading.

(107) *



However, n-Retroflexion is blocked by intervening coronals (mrd-na-, kṣved-ana-), which blocking effect should be characterized by the formation of the rule. Furthermore, the data in (106) show that both [anterior] and [distributed] are spread by n-Retroflexion. The inventory of coronal consonants in Sanskrit is argued by Steriade to be represented by the features in (108):

(108)

	anterior	distributed
t, s, n	+	+
ʈ, ʂ, ɳ, r	-	-
č, ś, ň	-	+

Both [-anterior] and [-distributed] must be spread in order to change [n] into [ɳ]. Because both [anterior] and [distributed] are spread, in order for the rule to spread a single constituent, it must be a node in the tree higher than the individual feature nodes that is spreading. Spreading the terminal features [anterior] and [distributed] would require a spreading of two constituents. However, as shown above, it cannot be the place node that spreads because spreading is not blocked by intervening labial or dorsal segments. Rather, the fact that more than one feature spreads, together with the fact that labials and dorsals do not block spreading, argues that it is the coronal node that spreads. Moreover, if the rule is characterized as spreading the coronal node, then we have an explanation for why intervening coronals block the rule. Coronals block the rule by virtue of having a coronal node.

For these reasons, Steriade proposes the rule in (109), which spreads the coronal node of a [-distributed] continuant (ʂ,r) onto the place node of a coronal nasal:

(109) Sanskrit n-Retroflexion (Steriade (1986)

```
 root           root
 |   \           |
supra [+cont]   supra
 |               |   \
place           place  \
 |               ‡   nasal
cor             cor
 |
[-dist]
```

This rule will not be blocked by intervening labials or dorsals because they have no coronal node to interfere with the spreading, and because there is no requirement that the target and the trigger occur on adjacent skeletal slots.

2.5.1.2 English Coronal Assimilation

Clements (1985:235) cites English coronal assimilation, by which a coronal assimilates in anteriority and distributedness to a following coronal, as evidence for the place node. This process could, however, be represented as spreading the coronal node, as noted by Halle (1986).

(110)

```
             x         x
             |         |
            root      root
           / |         |   \
          /  supra    supra  \
[-cont]      |         |    [+cons]
            place     place
             ‡         |
           coronal   coronal
             |
            [+ant]
```

Data illustrating (110) are given in (111) (from Clements (1985:236)).

(111)	/t/	/d/	/n/
__ θ	eighth	hundredth	tenth, enthuse
__ š,ž	white shoes	red shoes	inch, hinge, insure, enjoy
__ r	tree	dream	enroll

The data above could be accounted for by a spreading of the place node, because the segments in question are adjacent, so there will be no blocking effects, and because the only articulator node under the place node is the coronal node, so that spreading the place node is indistinguishable from spreading the coronal node. However, if the rule is characterized as a spreading of the place node, then there is no explanation for why it applies only between two coronals. Usually spreadings of the place node apply regardless of the articulator under the place node, as in the nasal assimilations in Kpelle, Dan, and Yoruba discussed above.[28]

2.5.1.3 Karanga Labio-Corono-Velar Simplification

In Karanga, in a labiovelarized coronal, the coronal articulation is deleted, as in (112) (data from Doke (p.211)).

(112)	txw,sxw	--> xw
	rYw	--> gw
	nŋw	--> ŋw

The process in (112) is easily represented as a delinking of the coronal articulator node, as in (113):

----

28. While English /t,d,n/ may assimilate to non-coronals, as in a possible pronunciation of <u>hit</u> <u>Ken</u> as [hIkken], or of <u>hit</u> <u>Peter</u> as [hIppitr], such assimilations are optional, as opposed to the obligatory assimilations in (111), and so do not bear on the formulation of the rule in (111).

```
(113)   root
          |
        supra
          |
        place
        / | \
   labial |  dorsal
        coronal
```

We might view this process in Karanga as yet another instance of the incompatibility of coronal and dorsal articulations in a language, as discussed above.

2.5.2 Labial Articulator Node

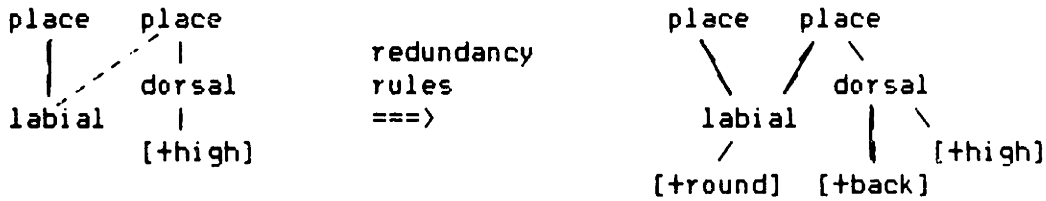
2.5.2.1 Tulu Vowel Rounding

There is a rule in Tulu which rounds /i/ to [u] after either a round vowel or a labial consonant, as shown in (114) (from Campbell (1974)).

(114) $$i \rightarrow u \;/\; \left\{ \begin{array}{l} [V,\ +\text{round}]\ (C\ (C)) \\ [C,\ +\text{labial}] \end{array} \right\} \_\_\_$$

Campbell gives the rule in 114), among others, as an argument that labial consonants and vowels must share some feature. Whatever feaeture labial consonants and round vowels have in common is the feature that spreads in (114). Campbell notes that "nothing in the feature system of shows that these 'labial attraction rules' are at all natural. There is no reason why [+anterior, -coronal] consonants (labials) should cause vowels to become [+round]" (p.53). In my system, the "feature" they share is the class node [labial]. Thus, Tulu rounding may be stated as in (115).

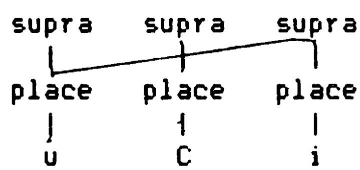
(115)



I assume that redundancy rules will interpret (i) a labial node in a vowel as [+round] and (ii) a dorsal node in a vowel with a labial node as [+back]. The spreading of labial in (115) is not blocked by intervening non-labial consonants, for these will have no labial node.

Rounding in Tulu must be a spreading of the labial node, as in (115). If the whole place node spread, then intervening consonants which are specified for place of articulation would block rounding, because their place nodes would block the spreading of the place node of the rounded vowel across the consonant(s).

(116) *



The rounding rule cannot just spread the feature [+round], on the other hand, because the labial consonant that triggers the rule need not be [+round]. Thus, the labial node, which unites labial consonants and round vowels, is what must be spread, in order to capture the fact that both (nonround) labial consonants and round vowels trigger the rule. These data, therefore, provide evidence for the need for a spreadable constituent, a class node, intermediate between the place node and the feature nodes. This intermediate class node is the articulator node "labial".

2.5.2.2 Chukchee

In Chukchee, there is a process of epenthesis which provides evidence for the class node labial. The epenthesized vowel in Chukchee is normally [I]. However, when the epenthesized vowel occurs in certain environments with labials, it becomes rounded.[29] Examples with epenthesis are given in (117), where the epenthesized vowel is set off by hyphens. (Recall that /c/ symbolizes a palatal stop.)

(117)

[I]	gel-I-tcin-I-c	'on the top of the sea-ice'	(658)
	ñalvŏl-I-čhIn	'the herd'	(658)
	n-I-np-u-kin	'old one'	(658)
	tIL-I-tIl	'the entrance'	(658)
	eleut-I-cə	'without head'	(658)
	tImc-I-leut	'hummock head'	(658)
	c-u-c-I-l	'one-eyed man' (<ccl)	(665)
	tirc-I-tir	'sun'	(689)
	kerg-I-ker	'light'	(689)
	itč-I-pIlvIntIn	'precious metal (i.e. gold)'	(658)
	pilh-I-pil	'famine'	(689)
	t-I-mnen	'he killed him'	(663)
	muL-I-mul	'blood'	(658)
	p-I-rgə?n	'thou hast plucked it'	(663)
	p-I-nlonen	'he asked him'	(663)
	p-I-ñ-I-l	'news' (<pñl)	(665)
	keñIčv-I-n	'boy'	(692)
	w-I-yowi	'sling' (<wyo)	(664)
[u]	itč-u-wil	'precious ware'	(658)
	eul-u-walat	'long knives' (</iwl+valat/)	(658)
	č-u-wipIt	'piece cut off' (<čvi)	(664)
	wukw-u-n	'stone'	(692)
	tImarakw-u-t	'I blamed thee'	(749)
	mul-u-mul	'blood'	(689)
	c-u-c-I-l	'one-eyed man' (<ccl)	(665)

----

29. Epenthetic [I] also becomes lowered (or backed) to [ə] in the environment of dorsals, as in lelanpInačh-ə-kai 'eyes (had) the small old man' (658), nitč-ə-kin 'heavy, dear' (658), and mitc-ə-mit 'blubber' (689).

[ŏ]	n-I-np-ŏ-kin	'old one'	(658)
	p-ŏ-cirgə?t	'they came'	(663)
	m-ŏ-cičin	'more numerous'	(663)
	v-ŏ-iaarkin	'he lets go (an animal)' ((vya)	(664)
	kenanm-ŏ-e?	'kill me!' ((kena-tm-gi?)	(749)
	n-ŏ-plukin	'small one'	(658)

The exact circumstances under which the rounded vowels [u,ŏ] surface instead of [I] are not clear. A necessary but not sufficient condition for [ŏ] seems to be the occurrence of [p] in the same syllable (either onset or coda). Similarly, in most of the cases with [u], the epenthesized vowel is either preceded or followed by [w] or [kw].[30] There even seems to be some optionality at work. Consider the pair in (118).

(118)	mInuňelm-I-k	'let us gather fuel'	(751)
	mInraqtIm-ŏ-k	'let us go home'	(751)

The forms in (118) show that in the same enviroment, between /m/ and /k/ (and even, it is likely, in the same morpheme), in one case the epenthetic vowel surfaces as [I] and in another case as [ŏ].

Nevertheless, even without knowing the details of the conditioning, it is clear that both the [+round] labials /w,kw/ and the [-round] labials /p,m,v/ condition rounding in the epenthetic vowel. Since [-round] labials cause rounding of the vowel, the process cannot be one spreading [+round]. Rather, the process must spread the class node, labial. This is thus evidence that /w/ is not only [+round], but also contains the labial articulator node, and that rounding of epenthetic vowels in Chukchee is a process which spreads the labial node, as in Tulu.

----

30. [kw] is a labialized [k], not a sequence of [k] plus [w], as Bogoras makes clear by his notation /wkw/, which signifies that the labialization runs throughout the /k/.

2.5.2.3 Nootka

The labial articulator node provides a means of representing simplifications such as occur in Nootka /kw,qw/ syllable finally. In Nootka, /kw,qw/ are simplified to /k,q/ at the end of a syllable. This is easy to represent as simply a delinking of the labial node, if there is a labial articulator node. As Campbell (1974) describes the simplification, "the only change is the loss of one articulatory gesture" (p.62). Such a delinking is motivated on the basis of syllable structure and marked segment types. It has been noted that segments which are marked or structurally complex often occur only in onset position in a language, the class of coda consonants being quite restricted. For example, in Yuma, the complex consonants /ky, xw, qw/ may not occur in syllable-final position, and /kw/ may be syllable-final but not word-final (Halpern (1946)). In this context, the simplification in Nootka is motivated as a process reducing the structural complexity of /kw,qw/. If /kw,qw/ were represented as simply a feature matrix containing [+round], then the fact that a segment containing [+round] is more marked than a segment not containing that feature would have to be stipulated, and would not fall out from the structure of the representation, as it does with the articulator nodes structure.

2.5.2.4 Relation Between Labial and Round

A further motivation for the representation of labial articulations as in (119a) rather than (119b)

```
(119)   a.      place                          b.      place
                  |                                    / / \ \
                labial                     [+labial] /     \ [-coronal]
                  |                            [a round] [+anterior]
               [a round]
```

concerns a process of labiovelarization in some Shona dialects noted by Doke (1931):

> "A peculiar phenomenon, worthy of special notice, occurs in budya, Karanga, and to a slight extent in Korekore and Tavara, when velar consonants followed by the semi-vowel w are pronounced; this is a species of <u>labialization</u> caused by contact of the lips before the velar sound, resulting in the forms pkw, bgw, mŋgw and mŋw instead of kw, gw, ŋgw and ŋw" (p.122).

Some examples he gives of this are given in (120).

(120)	pkwete (Kar.)	pkwete (bud.)	kwete (Zezuru)	"no!"
	bgwai (Kar.)			"sheep"
	mamŋgwana (Kar.)	mamŋgwana (bud.)		"tomorrow"
	mŋwana (Kor.)	(variant of [ŋwana])		"child"

In these languages, merger of a round vowel onto a consonant results in a bilabial closure. If round vowels were represented as [+round, -labial], and bilabial consonants as [+anterior, -coronal, +labial], then the naturalness of this process would not be reflected by the distinctive features at all: there would be no reason for the change [+round, -labial] --> [+anterior, -coronal, +labial]. However, in (119a), since labial means simply involving the lips as an active articulator, [+round] by definition must be labial. Therefore, linking [+round] from a vowel onto the x-slot of the velar entails interpolation of a labial articulator node, which explains the labialized consonant becoming bilabial. The data in (120) thus supports the representation in (119a), by which [+round] implies a labial articulator node.

Another difference between having two independent features, round and labial, in a feature matrix, versus having the labial articulator node dominating the feature round, is that the latter representation allows fewer combinations. Any segment that is either [+round] or [-round] of necessity includes a labial node. By contrast, in the matrix approach, a segment could be any combination of round and labial, in particular [-labial, +round] or [-labial, -round]. This dependence of [round] on labial is inherent in the definition of labial -- 'involving the lips as an active articulator'. Obviously, a segment could not be [+round], or [-round] (in the sense of having spread lips), without involving the lips as an articulator. The combinations predicted by the two approaches are shown in (121):

(121)
a. Labial Articulator Node

$$\text{labial} \qquad \begin{array}{c}\text{labial}\\ | \\ \text{[+round]}\end{array} \qquad \begin{array}{c}\text{labial}\\ | \\ \text{[-round]}\end{array}$$

b. Standard Theory

$$\text{[+labial]} \quad \begin{bmatrix}\text{+labial}\\ \text{+round}\end{bmatrix} \quad \begin{bmatrix}\text{+labial}\\ \text{-round}\end{bmatrix} \quad \begin{bmatrix}\text{-labial}\\ \text{+round}\end{bmatrix} \quad \begin{bmatrix}\text{+labial}\\ \text{+round}\end{bmatrix} \quad \text{[+round]} \quad \text{[-round]}$$

The data above, in which rounded segments are also labial, shows that the dependence between labial and round which results in the more limited inventory in (121a) is correct.

Note, furthermore, that any specification for the feature [round], even [-round], entails that the segment has a labial articulator node, or in traditional terms, is [+labial]. That [-round] segments are indeed [+labial] is shown by the glide-consonant alternation in Zezuru, by which a

[-round] vowel alternates with a labial consonant [B]. This alternation is described by Doke as follows:

> Zezuru and certain sections of the Korekore group have the distinction of using a peculiar denti-labial type of semi-vowel in place of the bilabial fricative, making in all three semi-vowels in those dialects. This we indicate by the symbol B.
>
> ...In its formation this unique sound has its origin in the abnormal vowel ɨ, which is formed with the tongue position of u but with the lips spread as for the vowel i. When ɨ is normally consonantalized, i.e. pronounced with such tensity and proximity of the vocal organs as to constitute a consonant it is found that the upper teeth just touch the lower spread lip, giving very much the position for normal v (Doke p.105).

The vowel /ɨ/ in Zezuru -- a high back vowel with spread lips -- I represent as in (122):

```
(122)          root
                |  \
               supra \
                |   [-cons]
               place
                / \
               /  dorsal
          labial    / \
            |  [+high] \
         [-round]      [+back]
```

The fact that the [-round] vowel in Zezuru becomes a bilabial when consonantalized argues for its representation as in (122), with [-round] attached to a labial articulator node. This, then, constitutes evidence for the dependence of the feature [round] on the articulator node labial, for even [-round] entails a labial articulator node.

Finally, labial consonants don't block round harmony. Therefore, if we assume that vowel harmony is performed without a separate vowel tier, as argued by Clements (1986), then the feature which labial consonants and rounded vowels have in common cannot be the feature that spreads in rounding harmony. Rather, we need two features: labial, which the labial consonants and round vowels share, and [round], which can spread past labial consonants in rounding harmony.

2.5.3 Dorsal Articulator Node

My separation of features onto articulator-tiers, as in (4), has revealed a curious asymmetry in the standard distinctive feature system regarding the three articulators: lips, tongue blade, tongue body. On the one hand, the features [labial] and [coronal] refer directly to the articulator involved. That is, if the lips are involved, whether in a bilabial or a labiodental, the sound is [+labial] in the standard system. Similarly, an articulation involving the front of the tongue is [+coronal] in the standard system, whether it is dental, alveolar, retroflex, and so on. But there is no corresponding feature in the standard system for "+tongue body" to be present whenever an articulation involves the tongue body.[31] I correct this asymmetry among the features with the representation in (4), in which the feature dorsal, meaning involving the tongue body as an active articulator, is introduced as parallel to the features labial and coronal.

In this section, I present evidence for this dorsal articulator node

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31. The reason why this gap has escaped attention is probably that in practice, the feature [-anterior] defines almost the same class as [+tongue body] would: a closure formed using the tongue body is always [-anterior], while closures not involving the tongue body are generally [+anterior].

from processes of vowel harmony and assimilation.

2.5.3.1 Fanti

Consider the case of Fanti. In Fanti, /r/ is an alveolar trill which assimilates in dorsal features to a neighboring vowel. This is described by Welmers (1946) as follows:

> The position of all but the trilling tip of the tongue is homorganic with, or at least attracted to, the position of the following vowel, if there is one, or else that of the preceding vowel. /r/ is therefore palatalized before /i/, velarized before /u/, and similarly affected to a lesser extent before /e,o/; the back of the tongue is low before /a/. If /r/ is final, the same variants occur after the same vowels. If the adjacent vowel is under the influence of /′/ [ATR -- i.e. i′ = [i]; i = [I]], the tongue seems to be more relaxed during the articulation of /r/ (p.13).

This, then, is a case of partial assimilation -- spreading just the dorsal node, and not the place node. Consider, for example, the velarization of /r/ before /u/ shown in (123).

```
(123)   root       root                      root      root
          |          |                         |         |
        supra      supra          ==>        supra     supra
          |          |                         |         |
        place      place                     place     place
          |         / \                        |   \    / \
       coronal  ↖  /  labial                coronal \  /  labial
         / |     dorsal    \                  / |   dorsal    \
  [-dist]  |       | \    [+round]      [-dist] |     | \    [+round]
       [-ant]      | [+back]                 [-ant]   | [+back]
              [+high]                              [+high]
```

Spreading just the dorsal node, as in (123), captures the fact that /r/ is not rounded before /u/ -- just velarized. If the whole place node were spread, then the labial node dominating [+round] would also spread. Also, if we adopt a convention of automatic delinking, by which linking to a segment a second specification for some feature results in automatic delinking of the previous specification, then if the entire place node were spread in Fanti /r/ assimilation, that would result in delinking /r/'s original place node, and /r/ would lose its coronal features. Rather, the tongue body node of the vowel links to the place node of the /r/ which dominates only a coronal articulator node. In fact, conceiving of the rule in this way captures the fact that it is precisely because /r/ lacks a tongue body node that it is a likely candidate for the assimilation of the tongue body features of the following vowel.

2.5.3.2 Vowel Harmony

Vowel harmony is not blocked by dorsal consonants in general. Therefore, dorsal place of articulation must be identified by some feature other than the features [back, high], which are spread in vowel harmony. If dorsal place of articulation were identified by [+back, +high], then dorsal consonants would block backness and height harmony. Rather, dorsal place of articulation in consonants is specified by the dorsal articulator node alone.

That dorsal consonants are, in the normal case, specified with just a dorsal node is shown clearly by the less common cases where some dorsal consonants do block harmony. These dorsal consonants which block harmony are those that are distinctively specified for [back] or [high]. For example, Clements and Sezer (1982) show that in Turkish, distinctively [-back] /k̑,g̑,l̑/ and distinctively [+back] /k,g,l/ block backness harmony.[32]

In Shona and Kinyarwanda velarization, [+back] is spread from a vowel onto a consonant, resulting in a dorsal consonant. I demonstrate in Chapter 3 below that velarization cannot be a spreading of the entire dorsal node. Therefore, velarization in Shona and Kinyarwanda shows that [+back] implies a dorsal node, because linking [+back] to the segment results in a dorsal consonant. Similarly, palatalization in Kinyarwanda, which is a spreading of [-back] from the following vowel, results in a [-back] dorsal consonant. These data show that specification for [back] entails specification of a dorsal node.

2.6 Impossible Feature Dependencies

The explanation of the dependencies in (4) in terms of independent articulators makes impossible certain types of feature dependencies in the feature hierarchy. Specifically, no two features which refer to different independent articulators may be in a dependence (i.e. dominance) relation. One feature dependency that is impossible under the view developed here is the dependency between [high] and [round] argued for by Archangeli (1985). Based on the operation of vowel harmony in Yawelmani, Archangeli (1985)

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32. This explanation of these facts requires that vowel harmony spreads single features, not articulator nodes. For if harmony spread the entire dorsal node, then any dorsal consonant, whether distinctively specified for [back,high] or not, would block harmony -- in the same way that intervening coronals block Sanskrit n-Retroflexion.

argues for a representation of vowel features in which [high] dominates [round], as in (124).

```
(124)                   [round]
                           |
                        [high, low]
                           |
                           x
```

The structure in (124) is proposed to account for the fact that in Yawelmani, whenever [high] spreads, [round] does also, although [round] can spread independently of [high]. However, given a universal hierarchical representation of articulator tiers, a structure such as (124), in which [round] is dependent on [high,low], is impossible. [Round] is a feature under the labial articulator node, and [high,low] are features under the dorsal articulator node. Thus, there can be no dependency between [round] and [high,low], because the articulator nodes they occur under, labial and dorsal, are independent in the hierarchy. Fortunately, the facts for which Archangeli proposed the structure in (124), the spreading of [round] in contexts where [high] has spread, receive an alternative solution in the analysis of Cole and Trigo (in prep). Cole and Trigo show that a hierarchical dependency between [round] and [high] is not required by the harmony processes in Yawelmani. Rather, they propose that the apparent dependency of [round] on [high] is the result of [round] harmony applying only in structures already linked for the feature [high], a phenomenon they argue exists in many other languages. (See Cole and Trigo (in prep) for details.) I conclude, therefore, that there is no evidence requiring a structure such as (124), and that the articulator node structure within the place node, which rules out (124), is correct.

2.7 Summary

In this chapter, I have demonstrated that there is a class of segments in human language, complex segments, which differ from consonant clusters in being represented on single x-slots and from contour segments in having multiple unordered articulations represented within the place node. I have shown that although both contour and complex segments are represented on single x-slots, they differ crucially in that the multiple articulations in a contour segment are phonologically ordered and behave as such with respect to satisfying the structural descriptions of phonological processes, whereas the multiple articulations in a complex segment are phonologically unordered, and behave as such in phonological processes. I have proposed a hierarchical structure within the place node, articulator nodes, to represent complex segments. This articulator nodes structure has found independent support from languages without complex segments. Thus, it is a universal property of phonological representation.

Chapter 3

DEGREE OF CLOSURE FEATURES

The feature hierarchy I have established so far is that in (1), in which degree of closure features are not yet included.

```
(1)                       root
                         /    \
              laryngeal        supralaryngeal
             / /  |   |          /           \
      constr /    |   |   soft-pal            place
        spread    |   |      |               /  |   \
             stiff    |    nasal        labial  |    \
                 slack                  /       |     dorsal
                                   round        |     | \   \
                                            coronal   |  \   back
                                             /  \    high low
                                           ant dist
```

In this chapter, I discuss what it is possible to establish regarding the position of degree of closure features in the hierarchy. The representation of degree of closure features in complex segments plays a crucial role in this investigation.

3.1 Place Features are Independent of Degree of Closure

First of all, as was discussed in Chapter 1 when arguing for the place node, it can be clearly established that there must be a node containing the place features which does not contain the degree of closure features. This is to allow assimilation of place features independently of manner features. If degree of closure features were represented anywhere within the place node, then spreading the place node in place assimilation would have the incorrect result of also spreading degree of closure:

(2)
```
supralar.        supralar.
   ‡ ________________|
   |
place            place
  |                |
deg. of clos.    deg. of clos.
```

The structure in (2) is shown to be incorrect by such processes as nasal assimilation in Kpelle, which was discussed in Chapter 1. Recall that in Kpelle, nasals assimilate in place of articulation to a following stop or fricative, and that regardless of the degree of closure of the segments they're assimilating to, the nasals retain [-cont] degree of closure. (Data from Welmers (1973:65;67)):

(3)	/N-polu/	[ḿbolu]	'my back'
	/N-tia/	[ńdia]	'my taboo'
	/N-kOO/	[ŋ́gOO]	'my foot'
	/N-kpiŋ/	[ḿŋgbiŋ]	'myself'
	/N-fela/	[ḿvela]	'my wages'
	/N-sua/	[ńʒua]	'my nose'

Another place assimilation process which shows the structure in (2) to be incorrect is the Sanskrit assimilation rule discussed in Chapter One. In this process, /s/ optionally assimilates to the place features of a following obstruent. Regardless of the degree of closure of the following obstruent, /s/ retains [+cont] degree of closure.

(4)	Indras	śuras 'the hero'			-->	Indraś śurah
	tas	'those-fem'	ṣaṭ	'six'	-->	taṣ ṣaṭ
	divas	'god-GENsg'	putras	'son'	-->	divaɸ putrah
	Nalas	kamam 'at will'			-->	Nalax kamam

3.1 Place Features are Independent of Degree of Closure

The results of assimilation in Kpelle and Sanskrit would be impossible to achieve with degree of closure features within the place node. Evidence of this type against the place node including degree of closure features abounds. Assimilation in place of articulation is one of the most common processes in phonology. Thus, we may safely conclude that degree of closure features must not be represented anywhere within the place node.

3.2 Degree of Closure in Multiply-Articulated Segments

Although it is clearly established that degree of closure and place features are independent for singly-articulated segments, the issue is not as clear for multiply-articulated segments. It has been argued, for example, that multiply-articulated segments require a degree of closure specification for each articulator (Sagey (in press)), and that clicks require independent specification of stop vs. affricate for each of their articulations (SPE). Such proposals, requiring that place features and manner features not be totally independent in these languages, would result in languages that have multiply-articulated segments being fundamentally different in their hierarchical representation of features from languages that do not have multiply-articulated segments. I will address in this section the question of whether degree of closure needs to be represented differently for simple versus multiply-articulated segments. At issue is not only the question of where degree of closure features are represented, but also the question of whether there exists a major typological distinction, reflected in a fundamentally different feature geometry, between simple-segment and complex-segment languages, or whether the only difference between the two is that complex-segment languages allow more than one articulator activated under the place node, while simple-segment languages do not.

Using the feature representation in (1), the difference between a simple and a multiply-articulated segment is that in the simple segment, there is only one articulator-node represented under the place node (i.e. only one out of labial, coronal, and dorsal), while in the multiply-articulated segment there are two or three articulator-nodes. In the simple segment, as far as interpretation is concerned, the degree of closure features may be specified anywhere in the feature hierarchy, and still be unambiguously interpreted as applying to the correct articulator, since there is only one. In the multiply-articulated segment, however, the specification of degree of closure for the various articulator nodes is less straightforward. Must degree of closure features apply to both articulators simultaneously? Obviously not, for there exist countless complex segments in which the degrees of closure of the two articulators are not identical, e.g. [skw] in Kinyarwanda [umuskwa] 'ant' and, extremely common, labialized and palatalized segments such as [gw, ty] in Nupe [egwa] 'hand' and [tya] 'to be mild'. Do we then need to specify the degree of closure for each articulator? If so, how is that represented; if not, and there is only one degree of closure specified, how do we know which articulator it applies to, and how is the degree of closure of the other articulator determined?

3.2 Degree of Closure in Multiply-Articulated Segments

In SPE, Chomsky and Halle argue that although the degrees of closure of secondary articulations are not universally predicted, they need not be represented underlyingly, since they are predictable within each language from other aspects of the segment.[1] For example, with respect to velarization, they state that

> while degree of narrowing never functions as the sole cue for differentiating two otherwise identical utterances, it is not true that in all languages the degree of narrowing involved in a particular sound is always predictable from universal phonetic principles. This becomes quite clear if we examine velarized consonants, which appear in various languages with radically different degrees of velar constriction (p.308).

Similarly, regarding labialization, they state:

> In consonants there are at least three phonetically different degrees of rounding. It appears, however, that the particular degree of rounding that obtains in each instance can be determined by the phonological rules of the language so that it is sufficient to indicate in the lexicon whether the given segment is or is not rounded (p.311).

Thus, they would represent just one underlying degree of closure for each segment, which would apply to the primary articulation, the degree of closure of the secondary articulation being derived by rule.

However, while Chomsky and Halle do not consider the "degree of closure" of secondary articulations phonologically distinctive, they do propose that the "manner of release" (instantaneous or delayed) of a

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1. A separate question is whether, independent of non-distinctiveness underlyingly, the degrees of closure of secondary articulations need to be represented at the surface in order to represent exactly how the sounds are pronounced in a particular language. If so, then the feature geometry would need to be able to accommodate secondary degree of closure specification at that level. This issue is addressed in Chapter Six.

secondary articulation may be phonologically distinctive. In their discussion of Hottentot clicks, they propose the features [delayed primary release] and [delayed secondary release], which apply to the coronal and velar constrictions of the clicks, respectively, to allow the two constrictions in each click independently to be either a stop or an affricate. Subsequent work in phonology has shown that the feature [delayed release] for affricates should be abandoned in favor of an autosegmental branching of [-cont][+cont] linked to one segment. Thus, Chomsky and Halle's argument for separate release features for the primary and secondary articulations would today be an argument for separate specification of degree of closure features for each articulator, exactly what Chomsky and Halle argued above that we didn't need.

I will examine in the following subsections the click systems of Hottentot and !Xũ̌, as well as the labiocoronal series of Margi, in order to determine whether the contrasts among the multiply-articulated segments in these systems require degree of closure features to be represented independently for each articulator.

3.2.1 Hottentot

As mentioned above, Chomsky and Halle use the click system of Hottentot (Korana dialect) to argue for separate release features for secondary closures. Similarly, in Sagey (1984), I argue that the representation of the distinctions among the various clicks requires separate degree of closure specification for each articulator.

3.2 Degree of Closure in Multiply-Articulated Segments

The clicks in Hottentot, all of which are coronal plus velar, Beach classifies according to influx and efflux. He states:

> The essential feature of a click is the <u>influx</u> of air into the mouth from without, in other words, the implosion. Clicks may therefore be classified in the first place according to the exact place of this influx and the exact manner in which it is made. But there is a second method of classification which must also be made, according to the <u>efflux</u> of air from the lungs. In Hottentot, the implosive part of the clicks is made by releasing the rim [of the airtight chamber formed between the tongue and the roof of the mouth] at some pre-velar point, while the back of the tongue remains against the soft palate. Before the following vowel can be made, the velar closure must also be released, and if air has been pressed against this closure from the lungs, a velar explosive will ensue before the vowel is uttered. ... This velar explosion may be either strong, weak, or affricative. Other effects which may be produced by the efflux of air from the lungs are nasalization, voicing, and other modifications produced at the glottis (p.75).

The Korana click system as classified by Beach according to influx and efflux is given in (5). (I show below that all of these involve velar closure, in addition to whatever other articulation at glottis or soft palate, even those that are not explicitly labeled as such. Velar closure is a defining characteristic of clicks.)

(5)

<u>Hottentot clicks (Korana dialect)</u>:

	Weak vel. plosive	Strong vel. affric.	Glottal plosive	Vel. Glot. affric.	Glottal fric.	Voiced nasal
Dental affricative	ǀ	ǀx	ǀ?	ǀx?	ǀh	ŋǀ
Denti-alveolar implosive	ǂ	ǂx	ǂ?	ǂx?	ǂh	ŋǂ
Lateral affricative	ǁ	ǁx	ǁ?	ǁx?	ǁh	ŋǁ
Alveolar implosive	!	!x	!?	!x?	!h	ŋ!

It may help in understanding the click symbols to note the following regularities: the "ǀ" symbol appears in every dental click; the "ǂ" in every denti-alveolar click; the "ǁ" in every lateral click; and the "!" in every alveolar click. Digraphs and trigraphs represent single, unitary segments, not sequences. In particular, glottal features and nasality are features of the click as a whole.

Chomsky and Halle accept Beach's assertion that "the principal difference between [ǀ] and [ǂ] is not in the place but rather in the manner of influx. [ǀ] is affricative, whereas [ǂ] is plosive" (p.77). They also interpret the distinction of plosive versus affricate as being more central than the distinction weak versus strong for distinguishing the "weak velar plosive" and "strong velar affricative" effluxes. Thus, they are led to posit distinctive stop vs. affricate releases for both the coronal and the velar constrictions, and they represent the differences among, e.g., [ǀ], [ǀx], [ǂ], and [ǂx] as in (6), using the features [delayed primary release] and [delayed secondary release] for the coronal and velar constrictions, respectively:

(6) Chomsky and Halle (1968) Classification of Korana Clicks:

	[ǀ]	[ǀx]	[ǂ]	[ǂx]
coronal	+	+	+	+
anterior	+	+	+	+
del.prim. rel.	+	+	-	-
high	+	+	+	+
back	+	+	+	+
del. sec. rel.	-	+	-	+

Similarly, in Sagey (1984), I argue that the above distinctions be represented as in (7), the coronal and dorsal articulations being distinguished by whether they branch for [cont] or not -- where [cont] may be specified independently for each articulator:

(7) <u>Sagey (1984) Classification of Korana Clicks:</u>

```
[ǀ]: [-cont][+cont]  [ǀx]: [-cont][+cont]  [ǂ]: [-cont]   [ǂx]: [-cont]
           \  /                  \  /              |                |
         coronal               coronal          coronal          coronal
            |                     |                |                |
            x                     x                x                x
            |                     |                |                |
          dorsal                dorsal           dorsal           dorsal
            |                    /  \              |               /  \
         [-cont]           [-cont][+cont]       [-cont]      [-cont][+cont]
```

However, there are arguments for considering the affrication in the above segments to be non-distinctive, i.e. predictable, in which case the argument for separate degrees of closure disappears because the predictable degree of closure features will not be specified. I argue in the next section against distinctive affrication in the influxes, and in the following section against distinctive affrication in the effluxes.

3.2.1.1 Influxes

Consider the four types of coronal articulation that make up the four possible influxes in Korana. First, the distinction between [ǀ] and [ǂ] could just as easily be ascribed to a place distinction as to a manner distinction. Beach gives palatograms for each of the clicks. The palatograms for [ǀ] and [ǂ] show a clear distinction, as Beach notes, in the area of contact of the tongue: "the amount of space on the palate left <u>untouched</u> by the tongue is less for [ǂ] than for [ǀ]" (p.77). For this reason, I distinguish [ǀ] and [ǂ] as [-distributed] and [+distributed], respectively. To further distinguish these clicks by [±cont] would be redundant. It would also falsely attribute phonological significance to the degree of closure, which seems to be universally predictable from the place features. Beach states: "In all these languages [that use the dental click] -- Hottentot, Bushman, and Bantu -- the dental affricative influx is produced in the same manner. All writers on these languages agree on the dental character of the influx, but practically none of them mentions its affricative nature" (p.76). I take these facts, that all of the dental clicks are affricated and that no writers found this affrication distinctive enough even to mention, as evidence that the affrication is not phonologically significant, but is, rather, perhaps universally predictable. Indeed, even in the English dental click expressing regret, etc., which is often spelled "tut" or "tsk", the influx is affricated.[2]

As for the distinction between what Beach calls the "lateral affricative" and "alveolar implosive" influxes, it is clear that they may be distinguished on the basis of [lateral] rather than [continuant]. Moreover, there does not exist in any language a lateral click that is <u>not</u> affricated (or fricative) (see, for example, the English lateral click used in spurring a horse, in which the influx is affricated); for that matter, there does not exist in any language in the world a lateral obstruent that is not either fricative or affricated. This universal phonetic fact about the (af)frication of lateral obstruents argues against representing the

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2. It is not, of course, the [+cor,+ant,-dist] place of articulation in itself that causes the dental influx [|] to be affricated universally. Non-click (non-affricated) stops do exist in some languages at this point of articulation, for example, [t] in Malayalam [kutti] 'stump' (Mohanan (1984:581)). However, such stops are differentiated from the click influxes under discussion by their egressive airstream mechanism. What seems to be universal is this: a [+anterior, -distributed] closure will always be affricated when accompanied by an <u>ingressive</u> airstream.

affrication of the lateral clicks in Hottentot phonologically. It is far preferable to distinguish these two influxes on the basis of [lateral], rather than as stop versus affricate.

In sum, the affrication in the dental [-distributed] and in the lateral click influxes is predictable from universal phonetic principles. It occurs in every case. It would therefore be wrong to specify it phonologically.

I have established a difference in distributedness between [ǀ] and [ǂ], and one in laterality between [ǁ] and all the others. What remains is to distinguish the alveolar [!] from [ǀ] and [ǂ]. Beach's palatograms (pp.76-9) show a clear place distinction between [!] and the clicks [ǀ] and [ǂ]. As the labels imply, the denti-alveolar [ǂ] and the dental [ǀ] are more anterior than the alveolar [!]. Thus, we may distinguish them as [+anterior] and [-anterior], respectively.

Incorporating the above conclusions, I represent the distinctions among the four coronal click influxes in Korana as in (8). Note that there is no mention of degree of closure necessary: the influxes, all coronal, are distinguished by the features [anterior, distributed, lateral], which distinctions are clearly indicated by palatograms of the various clicks.

(8) <u>Hottentot Click Influxes:</u>

	[ǀ]	[ǂ]	[ǁ]	[ǃ]
coronal	+	+	+	+
anterior	+	+	-	-
distrib.	-	+	-	-
lateral	-	-	+	-

3.2.1.2 Effluxes

I now turn to the click effluxes, to determine whether the affrication of the velar closure is distinctive, as assumed by Chomsky and Halle and by Sagey (1984); and if not, to determine by what features the effluxes are distinguished.

As noted above, the Korana dialect of Hottentot distinguishes six subtypes within each of the four types of click influx in (8). Beach's symbols and labels for these effluxes are given in the first column of (9); his descriptions of them in terms of the presence or absence, and the source, of air pressure against the velar closure at the time of its release are given in the second column of (9).

(9) <u>Description of Korana Click Effluxes</u>

		Pressure against Velar Closure
a.	k (weak velar plosive)	pulmonic, moderate
b.	kx (strong velar affric.)	pulmonic, strong
c.	kx? (velar glottalic affric.)	glottalic (ejective)
d.	n (nasal)	none (no audible velar release)
e.	h (glottal fricative)	none (no audible velar release)
f.	? (glottal plosive)	none (no audible velar release)

Since I have shown above that degree of closure is not distinctive for the coronal influxes, we could distinguish the effluxes in (9) by degree of closure without having to represent degree of closure as linked to any particular articulator. That is, since we are not using degree of closure for the influxes, it is available for distinguishing the effluxes, even if we restrict ourselves to a single, central specification of degree of closure for each segment, fitting click languages into a single typological category with simple-segment languages. Nevertheless, I will argue that the effluxes in Hottentot are not distinguished by degree of closure of the velar articulation, but rather are distinguished by glottal and nasal features only.

Consider first the effluxes in (9a-c). Beach's "weak velar plosive" efflux in (9a) is articulated with moderate air pressure from the lungs against the velar closure. That is, the velar release of this class of clicks is simply a voiceless unaspirated stop, [-spread glottis, -constr. glottis].

In (9b) is Beach's "strong velar affricative" efflux. This is articulated with "air from the lungs ... pressed strongly against the velar closure" (Beach p.83). In other words, it is aspirated. Like the aspirated non-click consonants /th/ and /kh/, which alternate with the aspirated affricates [tsh] and [kxh], this efflux alternates with aspirated affricative [kxh].[3] This affrication is not the principal distinguishing characteristic of this efflux, however, just as it isn't of the non-click /th,kh/. Although this efflux is usually affricated, it may also be pronounced without affrication as "a strong plosive [kh]" (Beach p.66). Thus, this efflux, which alternates between [kh] and [kxh], is best analyzed as /kh/ rather than /kx/, with the affrication which usually occurs being derived from its aspiration. This efflux, then, has the features [+spread glottis, -constr. glottis], in contrast to the efflux in (9a) which is [-spread glottis, -constr. glottis].

In (9c) is Beach's "velar glottalic affricative" efflux, which is pronounced with glottalic pressure against the velar closure. That is, it is an ejective. The affrication in this efflux may be derived from its ejective articulation, which is reasonable in light of Greenberg's (1970) observation that ejective consonants tend to be affricated. He notes that while affricates are "non-existent for injectives," for ejectives "they are

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3. The Korana non-click consonant system is as follows. The aspirated and ejective stops are phonetically affricated.

unvoiced:	p	t	k		fric:		s	x
voiced:	b	d	g		nasal:	m	n	
aspirated:		th	kh	h	trill:		r	
ejective:		(t?)	k?	?				

quite frequent and stable," and that "in two languages within the sample all the glottalic consonants are affricate ejectives" (p.130). Thus, I analyze this efflux as an underlyingly /k?/, that is, as a velar stop with glottal closure, and not as an affricate.[4] The ejective efflux is distinguished from the previous two by the features [-spread glottis, +constr. glottis].

Thus, the effluxes in (9a-c), which were considered by Chomsky and Halle (1968) and by Sagey (1984) to have distinctive specification of degree of closure (stop vs. affricate), are not, in fact, distinguished by degree of closure, but rather are distinguished by glottal features, as shown in (10). Given their feature classification in (10), better labels for these effluxes than Beach's would be simply "plain", "aspirated", and "glottalized", and I will refer to them as such.

(10)

	k "plain"	kh "aspirated"	k? "glottalized"
Dorsal	+	+	+
Spread Glottis	-	+	-
Constr. Glottis	-	-	+

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4. The non-click counterpart of this efflux, the ejective affricated velar [kx?], I also analyze as underlyingly /k?/, without affrication. By attributing the affrication in /th,kh,k?/ and the effluxes /kh,k?/ to their aspiration or glottalization, I have eliminated affricates from the underlying sound inventory of Hottentot. This is a nice result, because it regularizes the sound system of Hottentot to include three stop series: plain, aspirated, and glottalized. If the affricates were underlying, then we would have to explain why they couldn't occur <u>without</u> aspiration or glottalization, while the stops couldn't occur <u>with</u> aspiration or glottalization.

I will now consider the effluxes in (9d-f), all of which are pronounced without audible velar release. The question naturally arises whether there is actually any velar constriction in these at all, if none is heard. That is, it might be suspected that the so-called clicks with nasal, glottal fricative and glottal plosive effluxes are not clicks at all, but rather are simply implosives, combining only coronal and glottal constrictions. There is evidence, however, that segments with these effluxes do contain velar constrictions, and thus are properly classified as clicks.

Evidence for velar closure in the glottal fricative and glottal plosive clicks comes from a process of prenasalization which is described by Beach as follows:

> When [clicks with glottal plosive efflux] are immediately preceded in the same breath-group by a vowel ..., a very short voiced nasal stop is often (but not always) heard during the occlusion before the <u>influx</u> occurs. ... [For example, when the word [|?ui] follows a vowel,] during the first part of the occlusion of the [|?] (that is, while the tip, side-edges and back of the tongue are still in contact with the roof of the mouth), the soft palate may be lowered so that the air escapes through the nose, giving to the ear the effect of an [n] or [ŋ], or of [n] and [ŋ] together (p.85).

Also, "quite often, in both Nama and Korana, a click containing [the] glottal fricative efflux is pronounced with a slight voiced nasal efflux <u>preceding</u> the influx, in the same manner and in the same circumstances as have just been described in the case of the glottal plosive efflux" (p.86), i.e. this nasal is velar, too. However, there could be no velar nasal accompanying these clicks if there were no velar closure in the clicks themselves. Similarly, there must be a velar closure in the nasal efflux because "before the release of the click the sound is equivalent to a velar nasal consonant" (Ladefoged and Traill, p.10).

Also, although Beach does not give palatograms specifically of any clicks with this efflux, the palatograms he gives of [|, ǂ, ǁ, !] are intended as illustrative of all the clicks with those types of influx. For example, the palatogram of [ǂ] is given as "a fair sample of the many palatograms of this type of influx made by Salomon Witbooi" (p.77) and as an illustration of the entire series of denti-alveolar clicks [ǂ, ǂx, ǂ?, ǂh, ŋǂ]. Thus, it is likely, although unprovable, that Beach also obtained palatograms of the clicks with inaudible velar release [ŋ|, ŋǂ, ŋǁ, ŋ!, |?, ǂ?, ǁ?, !?, |h, ǂh, ǁh, !h] and found them to conform with those he gives in the grammar as illustrations. This would explain his certainty in describing them as articulated with velar constriction.

Finally, clicks with inaudible velar release are also heard in Zulu, which borrowed its clicks from Hottentot. Beach states that "ordinarily, the Zulu-Xhosa [|], [ǁ], and [!] are pronounced with silent velar release and no glottal efflux. But I have heard [|?], [ǁ?], and [!?] used when the speaker wished to be very emphatic" (p.85). Doke (1926) performed an x-ray study of this click on a Zulu speaker, and found that despite the lack of audible velar release, "the back of the tongue was raised to touch the soft palate" (p.124). Further evidence for the velar closure is that when a syllabic nasal, which must be homorganic, occurs before a click in Zulu, even before a click of the type under discussion, it is described by Doke as a velar nasal. Examples of homorganic nasals before non-click consonants are given in (11a); examples of velar nasals before the Zulu clicks that have variants with inaudible velar release are given in (11b),[5] followed by the page in Doke where they occur.

(11)

a.	u:pha:phE	'feather'	izim̲p?a:phE	(pl.)	(66)
	u:fu:du	'tortoise'	izim̲pf?u:du	(pl.)	(69)
	u:thi	'stick'	izi:n̲t?i	(pl.)	(71)
	u:ʃO:ʃO	'long pointed thing'	iziɲ̲ʃO:ʃO	(pl.)	(74)
	u:khE:zO	'spoon'	iziŋ̲k?E:zO	(pl.)	(76)
b.	u:|e:zu	'slice'	iziŋ̲g|e:zu	(pl.)	(136)
	u:ǁwE:ǁwE	'scab'	iziŋ̲gǁwe:ǁwE	(pl.)	(136)
	!ob'i:sa	'worry'	iŋ̲g!ob'i:sO	'trouble'	(136)

Thus, the lack of an audible velar release in a click does not necessarily imply the absence of a velar constriction. However, given that a velar constriction exists in the nasal, glottal fricative and glottal plosive clicks in Hottentot, we must explain why its release is inaudible.

For any release to be audible, there must be air pressure against the closure which, when released, will cause a burst of noise. Therefore, in the inaudible velar releases in the Korana clicks, there must be no air pressure against the velar closure. There are two means by which this lack of pressure could be accomplished. One would be to stop the pulmonic efflux of air at the glottis, to prevent pulmonic pressure from being exerted on the velar closure. That is, if the glottis is closed at the time the tongue is lowered, there will be no pulmonic pressure against the velar closure and no audible release (assuming no glottal pressure or

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5. Aspirated stops become glottalized after nasals. [g] before a click represents its voiced counterpart. Voiced consonants are prenasalized when preceded by the syllabic nasal. See [u:bEkE:na] 'quarrelsome person' vs. [izim̲mbEkE:na] (pl.) (p.66). m̲, n̲, etc. denote syllabic nasals.

suction is created by movements of the closed glottis). The other means would be to prevent build-up of pressure behind the velar closure by venting the air out through the nose. Under this explanation, whether the glottis is open or closed will have no effect on the pressure against the velar closure, and glottal pressure or suction will be impossible to create, regardless of glottal movements, because the air chamber behind the velar closure will be open to the nose. Both of these means have been proposed as explanations for the inaudibility of the velar releases in Hottentot glottal plosive and glottal fricative clicks.[6]

For example, in favor of the former explanation, Beach describes the glottal plosive clicks as follows:

> The glottis is closed during the occlusion made by the rim of the tongue ... on the roof of the mouth. This glottal closure prevents any air from the lungs being forced against the more forward velar closure. ... The pre-velar influx is first made while the velar and glottal closures remain intact. The velar release is then made <u>silently</u> while the glottal closure still remains. A third release is made at the glottis, where a weak plosive [?] is heard by reason of the fact that slight pressure was exerted from the lungs while the two outer closures (pre-velar and velar) were being released (p.84).

Similarly, Doke states that

> in Hottentot and Bushman, ... there are clicks devoid in sound of [the] velar element, and this can only be effected by a slight pause between an incomplete click [i.e. without velar release] and the following vowel, this pause being the stop of the glottal explosive. During this pause of the glottal stop the velar position of the tongue would be silently released and the click inaudibly completed. (fn. This I have ascertained to be the case in Chu: Bushman. ...) (p.126).

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6. The inaudibility of the velar release in the plain nasal click has not been explicitly dealt with.

Thus, Doke considers the "glottal fricative" efflux in Hottentot to be "aspirated after glottal stop" (p.299). Under Doke's explanation, this efflux must therefore be characterized both by [+spread glottis] (to produce the glottal friction) and by [+constr glottis] (in order to make the velar release silent). However, since [+constr glottis] and [+spread glottis] are physically impossible to articulate simultaneously, and since the glottal closure is in fact articulated before the glottal spreading, this efflux has to be a contour segment for glottal features: [-spread glottis, +constr. glottis] followed by [+spread glottis, -constr. glottis]. Beach, however, regards Doke's analysis of this click type as "erroneous" (p.86), stating: "Doke [considers] this type of efflux in Hottentot [to be] a combination of glottal plosive plus h, but I have never heard the plosive used (p.86). Beach instead describes this glottal fricative efflux as a sequence of silent velar release followed by [h], in which "the efflux does not commence until the velar closure is released" (p.86). He does not venture an explanation for the inaudibility of the velar release in this click.

The second proposal, attributing the inaudibility of the velar release to the escape of air through the nose, is argued for by Ladefoged and Traill (1980). Ladefoged and Traill recorded expiratory nasal and oral airflow, as well as the pressure of air in the pharynx (i.e. pressure against the velar closure), for each type of click efflux in Nama. Nama is a dialect of Hottentot, closely related to Korana, which has five of the six click effluxes of Korana. It lacks the glottalized click efflux.

For the plain and the aspirated click effluxes with audible velar release, [k] and [kh], Ladefoged and Traill's data show (i) no nasal airflow and (ii) an increase in pharyngeal pressure during the closure portion of the click. This is the normal result of closing off both the nasal and oral cavities while continuing to expel air from the lungs. These effluxes are therefore [-nasal].

However, for the nasal, glottal fricative, and glottal plosive effluxes without audible velar release, their data show (i) a large amount of nasal airflow (with vocal cord vibration in the nasal efflux, without vibration in the glottal fricative and glottal plosive effluxes), and (ii) no increase in pharyngeal pressure at any point during the closure portion of the click. These instrumental data clearly show that it is nasal release, and not glottal closure, that renders the velar releases in these clicks inaudible. First, there is nasal airflow in every click with inaudible velar release, and second, the lack of pharyngeal pressure that causes the release to be inaudible occurs not only in the glottal fricative and glottal plosive effluxes, but also in the plain nasal efflux, for which there is no evidence of any glottal closure and for which none has been proposed. Thus, all three of these effluxes are [+nasal], and the five click effluxes of Nama are distinguished as in (12):

(12) <u>Nama Click Effluxes</u>

	k	kh	ŋ	ŋh	ŋ?
Dorsal	+	+	+	+	+
Spread Glottis	-	+	-	+	-
Constr. Glottis	-	-	-	-	+
Nasal	-	-	+	+	+

The nasal character of the aspirated nasal and glottalized nasal click effluxes in columns four and five of (12) is also supported by their phonological behavior, that is, by their conditioning of nasalization on preceding vowels and of intrusive velar nasal stops, as discussed above. The fact that these clicks condition nasalization points to their being [+nasal] phonologically because this nasalization "is <u>never</u> used in conjunction with the two velar types of efflux [with audible velar release]" (Beach, p.87), and thus cannot be characterized as a universal accompaniment to click articulation.

Another advantage of explaining the silent velar release in some clicks in terms of escape of air through the nose, rather than in terms of glottal closure, is that it allows the straightforward and symmetric classification of the Korana clicks given in (13):

(13) <u>Classification of Korana Click Effluxes</u>

	k	kh	k?	ŋ	ŋh	ŋ?
Dorsal	+	+	+	+	+	+
Spread Glottis	-	+	-	-	+	-
Constr. Glottis	-	-	+	-	-	+
Nasal	-	-	-	+	+	+

By the classification in (13), the Korana click effluxes may be just (i) nasal or oral and (ii) plain, aspirated, or glottalized. They would therefore, under this classification, be better labeled as in the first column of (14), rather than by Beach's labels in the second column of (14).

(14) (Beach's label and notation)

a.	plain	k	(weak velar plosive	k)
b.	aspirated	kh	(strong velar affricative	kx)
c.	glottalized	k?	(velar glottalic affricative	kx?)
d.	nasal	n	(nasal	n)
e.	aspirated nasal	nh	(glottal fricative	h)
f.	glottalized nasal	n?	(glottal plosive	?)

By contrast, under the explanation attributing silent velar release to glottal closure, the classification would have to be as in (15):

(15) <u>Incorrect Classification of Korana Click Effluxes</u>

	k	kh	k?	ŋ	h	ʔ	
dorsal	+	+	+	+	+	+	
constr gl	-	+	-	-	-	+	-
spread gl	-	-	+	-	+	-	+
nasal	-	-	-	+	-	-	

There are many problems with (15): (i) The silent velar release in the nasal efflux is not addressed; it may be attributed to the nasal escape of air but then would fail to show any parallel to the other effluxes with silent velar release. (ii) The specification of the glottal fricative efflux requires the relatively more marked structure of contour glottal features, which furthermore does not occur anywhere else in Hottentot. (iii) The symmetry of the system in (14) is destroyed. (iv) The prenasalization conditioned by the effluxes in columns five and six is not explained, since they are [-nasal]. And, worst of all, (v) the velar glottalic affricative and glottal plosive effluxes are not uniquely specified. In order to distinguish these last two effluxes, we would have to appeal to a distinction in glottal pressure, the efflux with ejective velar release having glottal pressure caused by raising the closed glottis, the efflux with silent release having no glottal pressure. Not only would this require the addition of a glottal pressure or movement feature, but it seems to be factually wrong to attribute a distinctive function to glottal movement or lack of movement in these two clicks. Ladefoged and Traill note that in the glottal plosive efflux with silent velar release, which would under this view have glottal closure but no glottal movement, "during the glottal closure there is (naturally) no increase in pharyngeal pressure. But there is a very interesting nasal air flow at the release of the click. The voiceless nasal release accompanying the click is a phonetic detail that must be noted in a full description of this language ... It is possible that it is caused by a raising of the closed larynx while the soft palate is lowered" (p.10). That is, if there is pressure created during the glottal closure enough to cause nasal airflow, and caused by glottal movement, then we cannot attribute the lack of velar plosion in this click to the lack of glottal movement. In both the velar glottalic ejective and the glottal plosive effluxes there is velar closure, glottal closure, and glottal movement. The difference is that in the former the passage to the nose is closed so that the pressure created by the glottal movement causes a burst of noise at the velar release, while in the latter the passage to the nose is open, the pressure created by the glottal movement is realized as nasal airflow, and this nasal airflow reduces the pressure against the velar closure so that there is no burst upon its release.

To summarize the results of this section, I have shown that all of the clicks in Hottentot involve velar closure (even those with no audible velar release); and that affrication of that velar closure is not distinctive for any of the click types, but rather is predictable from the glottal features of the segment ([+spread glottis] and [+constr. glottis] each conditioning affrication). Cross-cutting the classification by glottal features, the effluxes may be either nasal or oral, correlating with inaudible or audible velar release, respectively.

Thus, the clicks in Hottentot may all be specified as [-cont], with the affrication of either influx or efflux determined by other properties of the segment (place of articulation for the influx, glottal features for the efflux). Since there is no need to specify a distinction of stop vs. affricate for either the coronal or the velar articulations in the clicks, there is obviously no need for independent degree of closure features for each articulator. Thus, the Hottentot clicks do not constitute evidence for a special feature geometry for complex-segment languages.

3.2.2 Margi

In this section, I present some additional evidence, from the complex segment system of Margi, that there is no need for degree of closure features for each articulator.

Margi contrasts a remarkable number of different labio-coronal complex segments. The inventory of consonants for Margi (from Ladefoged (1968) and

Hoffman 1963)) is given in (16):[7]

(16) Margi Consonant Inventory

Single POA						Labiocoronals			
lab.	alv.		lat.	pal.	vel.	alv.		lat.	pal.
p	t			c	k	pt			
b	d			j	g	bd			
?b	?d				?	?bd			
	ȼ	č				pȼ	pč		
	ʒ̸	ǰ				bʒ̸	bǰ		
f	s	š	ɬ	ç	x	ps/fs		pɬ	pç/fç
v,w	z	ž	ɮ	ʝ	ɣ	bz/Bz		bɮ	bj/Bj
m	n			ɲ	ŋ	mn			mɲ
h									
w	r		l	y					by
?w				?y					
mp	nt			ɲc	ŋk	mnpt			
mb	nd			ɲj	ŋg	mnbd			
	nc	nc				mnpc	mnpč		
	nj	nj				mnbj	mnbǰ		
			nɬ				(mnpš)	mnpɬ	
								mnbɮ	

Labialized					
pw	tw				kw
bw					gw
?bw					
fw	sw		ɬw		
vw					
mw					ŋw
	ntw				ŋkw
mbw					ŋgw
	nȼw				

First, I give some background on the Margi labiocoronals and establish that although they were derived historically from consonant clusters

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7. I follow here Ladefoged's phonetic description of the Margi prenasalized labiocoronals. Hoffman represents, e.g., prenasalized /pt/ as /mt/; Ladefoged as /mnpt/. I take the liberty of translating forms found in Hoffman into Ladefoged's notation.

created by syncope, they are now single segments.

Historically, the labiocoronals "resulted from the loss of a vowel separating two consonants" (p.228), i.e., CV < *CCV < *CVCV. The disyllabic CVCV forms from which the Margi forms derive can be found in closely related languages:[8]

(17)	Bura		Tera/Bata	
children	bzər	(Margi)	bəsonka	(Tera)
to forge	bɬə	(Margi)	bəɬə	(Tera)
to kill (many)	bɬə-na	(Margi)	bəɬa	(Pidlimdi)
monkey	pču	(Margi)	fiče	(Ga'anda)
sun/day	pči	(Bura)	fotə	(Gudu)
to die	mnpti	(Margi)	mədə	(Tera)
chief	ptəl	(Margi)	kutira	(Ga'anda)
grass	psar	(Margi)	wuzən	(Tera)
	(cf. kusar	(Bura))		

Fusion into labiocoronals is no longer productive in Margi. Clusters of labial or velar plus coronal that are derived or borrowed, such as those in (18),

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8. Evidence for this derivation is also that except in reduplicated forms, "the labio-alveolar consonants are limited almost entirely to initial position ... [and] the length of words containing these complex consonants tends on the average to be shorter than that of the vocabulary as a whole" (p.228). Note that in the last two forms, /k/ becomes /p/. Thus, "these co-articulated consonants resulted not only from a sequence of labial plus alveolar, but also from a sequence of velar plus alveolar" (p.228). I have followed Ladefoged's characterization of prenasalized labiocoronals rather than Hoffman's throughout this discussion. Ladefoged represents as /mnpt/ what Hoffman represents as /mt/. Often, it is possible to find the same form in both grammars, as when Ladefoged cites /mnptagU/ and Hoffman /mtagU/ for 'bush'. Here, I have no form in Ladefoged to confirm the pronunciation of 'to die' as /mnpti/ rather than as /mti/ as Hoffman cites it. However, Ladefoged is consistent in his interpretation of Hoffman's /mt/, so I cite the form as /mnpti/.

(18)

ʄibʧəni	'to be surprised'	(cf. Hausa aʄab(a) 'surprise')	(145)
ɗəkʧəni	'to molest'		(145)
kalakʧəni	'to surround'		(145)

are not labiocoronals because of facts such as /b/ and /ʧ/ not agreeing in voicing in /bʧ/ -- all labiocoronals agree in voicing.

A synchronic syncope process still exists in Margi, which has CVC syllable structure. Examples of syncope are given in (19):[9]

(19)

tətku	'one'	~	tətəku	(106)
aʧku	'it is becoming'	~	aʧuku	(39)
ənʧka	'stone'	~	ənʧəka	(39)
nwazgə'i	'a rat'	~	nwazəgə'i	(39)
Mičkəra	(a village)	~	Mičikəra	(39)
apkərgu	'how did you spend the day'	<	pəku 'to spend the day'	(39)

Labiocoronals, although historically derived by syncope, differ from clusters derived synchronically by syncope, in that the latter reduplicate as clusters, while the labiocoronals reduplicate as single segments. As Hoffman states, only the initial consonant, which may be either "simple or compound" (p.157) reduplicates. Thus, clusters derived by syncope reduplicate the first consonant only:[10]

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9. Hoffman states that this syncope process is limited to the vowels /e,i,u/ occurring between "an alveolar, alveopalatal or palatal and k or g, but sometimes also between p and k" (p.106). We have seen, however, that the historical fusion from clusters into labiocoronal complex segments occurred only in clusters of the order labial or velar plus coronal. Hence, the productive syncope process that Hoffman describes here cannot result in labiocoronals, because it is restricted to sequences ending in /k/ or /g/. This restriction on syncope which excludes possible clusters leading to labiocoronals is probably not a coincidence, but I have no explanation for it.

10. Note that the affricate /ʧ/ reduplicates as a single segment.

(20)

s(u)kudə (skudə)	'to push'	səskudə	'to push bit by bit'	(160)
ȼkwar(i)	'to touch'	ȼəȼkwar(i)	'to touch (many things)'	(160)

In (20), it is the syncopated form of 'to push', skudə, that is reduplicated, because in the reduplicated form, there is no vowel between the second /s/ and /k/. Compare the derivation: tapəra 'to vomit' -> tatapəra 'to vomit many times'. If reduplication were applying to the form sukudə, we would thus expect *susukuda on analogy with tatapəra. We cannot apply syncope after reduplication to derive suskuda from *susukudə, because we would then expect tatapəra -> *tatpəra. Note, furthermore, that the elided vowel in /skudə/ was a /u/. If this vowel were present in the form that reduplication applied to, the first vowel in the reduplicated form would also be /u/, yielding *suskudə, rather than the default /ə/, as in səskudə.

In contrast to the clusters above, labiocoronal segments reduplicate as units:

(21)

a. Iterative, intensive, or extensive action

mňa	'to rebuke'	mňamňa	'to rebuke very much'	(158)
mnbʒə	'to spoil(intr.)'	mnbʒəmnbʒə	'(many things) to spoil	(158)
mnpȼaku	'to pick up'	mnpȼəmnpȼaku	'to pick up in many places'	(159)
mnptə	'to die'	mnptəmnptə	'(many people) to die'	(158)

b. Participle

bdə	'to chew'	bdəbdə	'chewed'	(161)
psə	'to dye'	psəpsə	'dyed'	(29)
pȼa	'to roast'	pȼapȼa	'roasted'	(29)
bɬə	'to forge'	bɬəbɬə	'forged'	(161)
mnbʒə	'to spoil(intr.)'	mnbʒəmnbʒə	'spoiled'	(161)
mnptə	'to die'	mnptəmnptə	'dead'	(161)
mnpɬə	'(food) to rot'	mnpɬəmnpɬə	'rotten'	(161)
mnpȼə	'to sprout'	mnpȼəmnpȼə	'sprouted'	(161)
ptə	'to be insufficient'	ptəptə	'insufficient'	(162)
pčə	'to wash; to be washed'	pčipčə	'clean, washed'	(162)

mnpɬadə	'to point'	mnpɬamnpɬadə	'pointed'	(165)
bɮal	'to fry'	bɮabɮal	'fried'	(28)

The unit status of the labiocoronals is also supported by their description in the grammars. Newman and Ma (1966) state that the Margi labiocoronals were derived by "independent phonemes fusing to form unit phonemes" (p.225); they state that phonetically, the labial and coronal are coarticulated, and that "phonemically, [labiocoronals] fully qualify as unit phonemes," as argued by Hoffman and Ladefoged.

Maddieson (1983), however, argues that labiocoronals and prenasalized segments in Bura, a close relative of Margi, are consonant clusters, rather than complex segments. He argues, first of all, that labiocoronals are phonetic sequences of labial followed by coronal, and that they have a longer duration than single consonants. If his observations are correct for Margi, also, then that would remove the phonetic motivation for the representation of labiocoronals and prenasalized consonants on single x-slots. However, as Maddieson notes, we will still need to represent them on single x-slots if there is phonological motivation for their being single segments. Such phonological motivation would be their behavior as single segments in reduplication, as shown in (21). Maddieson argues that the reduplications in (21) are not evidence for labiocoronals being single segments, because he analyses them as reduplications of the initial syllable, rather than of the first consonant and vowel. However, this analysis is incorrect, at least for Margi. Reduplications in Margi are of only two types: total reduplications, as in (22), and reduplications of the first consonant and vowel, as in (23).

(22) Total Reduplications

bəl	'to break'	bəlbəl	'broken'	(161)
baŋ	'to ache'	baŋbaŋ	'aching'	(161)
duwa	'to hide'	duwaduwa	'hidden'	(161)
gəla	'to measure'	gəlagəla	'measured; right sized'	(162)
fəvəl	'to singe'	fəvəlfəvəl	'singed'	(161)
kungura	'to blister'	kungurakungura	'covered with blisters'	(162)
ȼagalə	'to gather'	ȼagaləȼagalə	'gathered together'	(163)

(23) CV Reduplications

ndal	'to twist'	ndandal	'to twist around many things'	(159)
ŋəl	'to abuse'	ŋəŋəl	'to abuse many times'	(159)
mwal	'to sour'	mwamwal	'sour, acid'	(165)
səl	'to fry'	səsəl	'fried'	(165)
ŋgwal	'to be bent'	ŋgwaŋgwal	'curved, bent'	(32)
nȼəl	'to bec. wise'	nȼənȼəl	'wise, clever'	(31)
ŋgulzə	'to stare at'	ŋguŋgulzə	'(many people) to stare at'	(159)
ntədna	'to pull away'	ntəntədna	'to pull away in many places'	(160)
yalna	'to take off'	yayalna	'to unwrap (many covers)'	(160)
ŋərzə	'to roll on the ground'	ŋəŋərzə	'pushed along on the ground'	(165)

If the reduplications in (23) were reduplications of the first syllable, then we would expect *ndalndal, *mwalmwal, *səlsəl, *ŋgulŋgulzə, *ntədntədna, *yalyalna, and *ŋərŋərzə, rather than the reduplications shown. The forms in (23) show that the coda is never reduplicated in a partial reduplication, and hence that partial reduplications must be reduplicating just the first consonant and vowel. The only way for a coda to be reduplicated is if the entire form is reduplicated, as in (22). Thus, since partial reduplications reduplicate the first consonant and vowel, the partial reduplications in (24) show that the labiocoronal is a single consonant.

(24)

mnpȼaku	'to pick up'	mnpȼəmnpȼaku	'to pick up in many places'	(159)
mnpȼadə	'to point'	mnpȼamnpȼadə	'pointed'	(165)
bɮal	'to fry'	bɮabɮal	'fried'	(28)

Maddieson also argues that labiocoronals and prenasalized consonants are syllabified as two segments, closing the preceding syllable where possible word-internally and being syllabified by a special onset-incorporation rule otherwise. However, I maintain that evidence from word-internal clusters points to labiocoronals and prenasalized stops being single segments. Consider the words in (25).

(25)

a.	kwacirmba	'armlet'	(261)	
	ñarmbwa	'his entrance'	(285)	
b.	kərnda	'themselves'	(20)	
	anañirnda	'they gave him'	(34)	
	umbwarnda	'their house'	(34)	
	mərnda	'their mother'	(81)	
	nərndən	'gun'	(244)	
c.	ŋkərŋkər	'cut out'	(30)	
	bzərŋkwa	'girl'	(41)	
	ŋgurŋgur	'stirred'	(163)	
	bəlŋgəri	'to break & put on top'	(134)	(bəl + ŋgeri)
	ndalŋgəri	'to throw on top, over'	(134)	(ndal + ŋgeri)
d.	... armña ...	'at the side of'	(51)	
	çirmñakuda	'Hirmnyakuda' (a name)	(285)	
	awałəpčirmnbdə	'an owl'	(51)	
	armnpta	'journey'	(259)	

The data in (25a) show prenasalized /mb/ after /r/. In (25b) is prenasalized /nd/ after /r/. (25c) shows prenasalized /ŋk/ and /ŋg/ after /r/ and /l/. Finally, (25d) shows labiocoronal /mñ/ and prenasalized labiocoronal /mnbd/ and /mnpt/ after /r/. Under my assumption that labiocoronals and prenasalized consonants are single segments, their occurrence in word-internal consonant clusters is not surprising. I analyze the forms in (25) as being of the syllable structure

```
σ     σ
|\   /|
V C C V.
```

If, however, prenasalized consonants and labiocoronals are consonant clusters, as in Maddieson's analysis, then the forms in (24) would have to be syllabified as in (26a) or (26b):

```
(26)    a.      σ       σ                 b.        σ       σ
                |\    //|                           |\      /|
                V C C C V                           V C C C V

                e.g.    ar.nda                      e.g.    arn.da
```

The syllabification in (26a) creates an onset, /nd/, which violates sonority sequencing within the syllable. If the nasal is an independent segment, then it would be expected instead to syllabify as in (26b), which does not violate the sonority hierarchy within the syllable. However, if the nasals in (24) are syllabified syllable-finally as in (26b), then there is no explanation for the fact that the syllable-final nasal is in every case homorganic with the following consonant. Syllable-final nasals are not, in general, required to be homorganic in Margi, as shown by the data in (27).

(27)

ɗanba	'to know well'	(ɗanə + ba)	(122)
çanba	'to send'	(çanə + ba)	(122)
ƙanba	'to fill up'	(ƙanə + ba)	(123)
ənčala čančan	'empty calabash'		(195)
baŋbaŋ	'headache'		(214)
samsam	'slowly, carefully'		(233)

Only if the nasal consonant sequences in (25) are single, prenasalized, segments is their homorganicity explained.

Additional support for prenasalized segments and labiovelars being single segments is that they may also occur as the first member of consonant clusters, as in (28):

(28)

a.	ənɛ́ka	'stone'	(39)	(~ ənɛ́əka)
	ŋwančci	'girlfriend'	(64)	
b.	əmnpčka skwar	'soup pot'	(38)	

Having established that the labiocoronals in Margi are single segments, let us now turn to the question of whether their representation requires separate degrees of closure for the labial and coronal articulations. Since there is a contrast among /pt,pɛ́,ps/, it could be argued that degree of closure must be represented independently for the labial and coronal articulators, to allow a [-cont] labial articulation to cooccur with a [+cont] coronal articulation, or with a [-cont][+cont] one. However, to make this move and allow independent degree of closure for each articulator is to ignore the systematicity in the data and to predict that the complementary combinations of /pft/ and /ft/ should also occur. No such combinations occur. The systematicity in the data is that in a labiocoronal segment, the labial articulation is always a stop.[11] Given this restriction on the labiocoronals, it would be possible, and even preferable, not to represent the degree of closure for the labial articulation in a labiocoronal. Rather, the distinctions among the various labiocoronal segments may be represented simply by a central specification of either [-cont] for [pt], [+cont] for [ps], or branching [-cont][+cont] for [pɛ́], as in (29).

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11. It may, however, optionally become a fricative in combination with a coronal fricative, so that /ps/ may be realized as [fs]. Even so, the fact remains that the degree of closure of the labial articulation is not distinctive.

<table>
<tr><th>(29)</th><th>pt</th><th>ps</th><th colspan="2">p¢</th></tr>
<tr><td>labial</td><td>+</td><td>+</td><td colspan="2">+</td></tr>
<tr><td>coronal</td><td>+</td><td>+</td><td colspan="2">+</td></tr>
<tr><td>cont</td><td>-</td><td>+</td><td>-</td><td>+</td></tr>
</table>

The degree of closure of the labial articulation, under this view, would be specified only at the level of phonetic interpretation. This, of course, makes the prediction that [ps] will behave as [+cont] with respect to the phonology of Margi. If it turns out that [ps] functions as [-cont] or as an affricate, it will be necessary to represent degree of closure independently for each articulator in Margi.

The prediction that /ps,bz,.../ will function phonologically as [+cont], despite their containing phonetically [-cont] articulations, is supported by the inventory of prenasalized segments in Margi. Margi allows prenasalization only of stops or affricates, i.e. of segments which contain [-cont] (or which are [-cont] on the left edge), as noted by Hoffman (1963:29). An apparent exception to this generalization is the well-formedness of prenasalized laterals such as /nɬ/ in [enɬelam] 'yeast' (Hoffman p.32). However, laterals in many languages function as [-cont]. It has been argued, for example, that in Portugese, the voiced obstruents surface as stops when following a [-cont] consonant, including /l/ (Lozano (1979:120)).[12]

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12. Similar proposals, also dependent on the non-continuant nature of /l/, have been made regarding stop-spirant alternations in Spanish (e.g. Lozano (1979)). However, there are problems with this type of account for the Spanish data whose resolution might lie in assuming /l/ to be neither [+cont] nor [-cont], as has been pointed out to me by Jim Harris (p.c.). I do not know whether the same problems arise in Portugese.

(30)	pomba	[põmba] 'dove'	
	albufeira	[aɫbufair]	'salt lagoon'
	Lisboa	[ližBoa]	'Lisbon'

For /l/ to act as [-cont] with respect to some phonological processes is entirely natural, given its articulation in which the center of the front of the tongue touches the roof of the mouth -- i.e. is articulated to the degree [-cont]. Assuming, then, that it is a true generalization about Margi that it disallows prenasalized fricatives, the lack of prenasalized /ps,bz/ is evidence that they are phonologically [+cont], i.e. that only the degree of closure of the coronal articulation, which in these is [+cont], is phonologically significant.

Among the labiocoronals, there is one apparent counterexample to the generalization that fricatives may not be prenasalized:

(31) mnpš mnpšalmeni 'a tall, long-legged bird' (31)

Since there is only one word given with /mnpš/, it is possible that this example was mis-recorded, and actually is an example of /mnpč/. Support for this hypothesis is Hoffman's comment that "in the nasal compounds mǯ, mǰ, nǯ, nǰ sometimes the plosive element is articulated rather faintly, especially in slack pronunciation, so that the impression is rather that of an mz, mž, nz, nž. ... In a lesser degree this is true also for nć, which (rarely) might sound like ns" (p.31). (Recall that Ladefoged would represent **mǯ, mǰ, mz, mž** as **mnbǯ mnbǰ, mnbz, mnbž.**) Thus, it is possible that the putative prenasalized fricative [mnpš] is actually a prenasalized affricate [mnpč], mistaken for a fricative because of the process that Hoffman mentions. As discussed above, prenasalized /mnpɬ/ and /mnbɮ/ are not examples of prenasalized [+cont] segments because /ɬ, ɮ/ in Margi function as [-cont]. (Hoffman also cites as prenasalized fricatives /mnbɟ/ and /mnpç/. I will not deal with these, because they have been attested only between vowels, in which environment "it is hardly possible to decide whether they are ... nasal compounds or a heterosyllabic juxtaposition of a nasal and another consonant" (1963:32), since Margi allows CVC syllables.)[13]

The labiocoronal segments just discussed are not the only complex segments in Margi combining both labial and coronal articulation. Margi also contains a series of labialized consonants, shown in (29), which includes the labialized coronals /tw, sw, ɬw/. The labialized consonants in Margi are single segments. Hoffman describes them as "consonants with simultaneous lip-rounding ... which are <u>spelled</u> with a <u>w</u> following [the] consonant" (p.27) (emphasis added). Also, as the data in (32) show, labialized consonants reduplicate as single segments, not clusters:

(32)

bwa	'to cook'	bwabwa	'cooked'	(161)
mwal	'to become sour'	mwamwal	'sour, acid'	(165)
gwadə	'to mix'	gwagwadə	'mixed'	(164)
ŋwadə	'to stalk, to sneak'	ŋwaŋwadə	'to stalk, sneak'	(159)
hwa	'to boil'	hwahwa	'boiled'	(161)
ŋwivə	'to become thin'	ŋwiŋwivə	'emaciated, lean'	(165)

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13. For Bura, Maddieson (1983:308-9) cites, in my notation, /mnpsəka/ 'maternal uncle', /mnpši/ 'corpse', /mnbža/ 'be enough', /mnpçi/ sorghum', /mfwa/ 'tree', /mvwa/ 'Kanuri person', /nzi/ 'to sit', and /ŋYi/ 'to be full', which apparently contain prenasalized fricatives. He does not explicitly state whether these occur in Margi. Furthermore, Hoffman notes that in the literature prenasalized affricates are often spelled as prenasalized fricatives (p.30-1). Thus, I will assume that Hoffman and Ladefoged's representations of the prenasalized consonant inventory of Margi are correct.

Thus, Margi contrasts the following labialized coronals and labiocoronals, all of which are single segments.

(33)	tw	vs.	pt
	sw	vs.	ps
	ɬw	vs.	pɬ

I have shown above that the labial articulation in /pt,ps/ has predictable degree of closure, while the coronal articulation does not; and that therefore, if we are to maintain the hypothesis that every segment has only one specification of degree of closure, then the single degree of closure specification in /pt,ps/ will have to apply to the coronal articulation. Similarly, it is clear that the degree of closure of the coronal articulation in the labialized coronals /tw,sw/ is also distinctive, since the only difference between /tw/ and /sw/ is the degree of closure of the coronal articulation. This means that in /tw,sw/, just as in /pt,ps/, a single specification of degree of closure will have to apply to the coronal articulation, with the degree of closure of the labial articulation being derived, if we are to maintain our hypothesis.

How, then, may we distinguish /pt/ from /tw/, or /ps/ from /sw/, if we have ruled out phonological specification of degree of closure for the labial articulations in these segments? Is this evidence that we need separate degrees of closure for each articulator, in order to allow us to represent different degrees of closure for both the labial and the coronal articulations in /pt,tw/ and thus to distinguish them?

There is no need for phonological specification of degree of labial constriction to distinguish these segments, for they already contrast in another feature, the place feature [round]. /pt/ is [-round], /tw/ is [+round]. We may thus derive the degree of closure of the labial articulation from its place features: [-round] -> [-cont]; [+round] -> [-cons].[14] The specification of Margi /pt, ps, tw, sw/, therefore, is that in (34), in which each segment has only a single specification for degree of closure, which applies to the coronal articulation:

(34)

	pt	ps	tw	sw
cont	-	+	-	+
coronal	+	+	+	+
labial	+	+	+	+
round	-	-	+	+

Interesting in this regard is the lack of rounded labiocoronals in Margi, e.g. [ptw]. The prediction of my characterization of Margi labialized coronals and labiocoronals is that if a labiocoronal were rounded, it would lose its labial closure (/pt/ + /w/ --> [tw]), because adding [+round] to [pt] would convert it exactly into [tw], as can be seen in (34). Although neither Hoffman nor Ladefoged lists rounded labiocoronals in their sound inventories of Margi, Hoffman does cite one form which might be interpreted as a rounded labiocoronal, derived by suffixation of /-wa/.[15]

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14. On the degree of closure of rounded labials /pw,bw,?bw,fw,vw,mw/ which are [+round] but not [-consonantal], see below.

15. Hoffman states that "the derivatives in /-wa/ mostly indicate that the action is done in the direction 'into' something. In other cases they mean 'instead of'. The suffix /-wa/ is also frequently used to indicate that

(35) bɬə 'to forge' + wa -> bɬwa 'to forge a tool instead of another one' (147)

The "rounding" in this case, however, would be better analyzed as a sequence of /bɬ/ plus /w/, the final /ə/ of /bɬə/ merely having been deleted. Hoffman cites other examples in which the final vowel of the stem is not deleted, e.g.,

(36)
naçə 'to trample' + wa -> naçuwa 'to trample on a thing and divide it into parts' (148) (ə --> u / __ w)

and he states that "after alveolars it is sometimes difficult to decide whether a vowel [ə] or [u] ought to be written before the /-wa/ or not" (p.147). Therefore I do not consider /bɬwa/ a counterexample to the claim that labialized labiocoronals do not occur.

To summarize the results of this section, the distribution of labiocoronal oral and prenasalized segments in Margi points to an analysis under which they have phonologically only a single, central specification for degree of closure. The labialized coronals also conform with this analysis. The problem now is how to characterize the fact that this specification for degree of closure is applied to the coronal articulator in Margi and not to the labial articulator. This same problem, the need to be able to characterize which articulator the degree of closure features of a segment apply to, arises with respect to the consonant system of !Xũ, a Bushman language.

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the object is divided into (two or more) parts" (p.149).

3.2.3 !Xũ

In this section, I examine the click system of !Xũ, which is similar in many respects to that of Hottentot, but more extensive. First of all, and unlike Hottentot, in !Xũ, clicks are not restricted to the word-initial position, but may occur also word-medially, as the examples in (37) show. (Each word is followed by the page in Snyman where it occurs.)

(37)

gwaǂ?a	'yesterday'	(7)	tshinǁ?ha	'to shoot'	(65)
kx?erug|wae	'yellow weaver'	(22)	ǁao|xom	'to save'	(22)
ǁeuǁxorɔ	'brown hyena'	(31)	seuǁwa	'tape recorder'	(45)
žu|?hwa	'Bushman'	(45)	kaani|ei	'pig'	(47)
ǂxwaǂ?a	'sugar cane'	(52)	gǂxeiǁ?ha	'genital area'	(52)
n!anagǂxu	'Indigofera sp.'	(52)	!un!a?a	'Grandfather'	(54)
!a|ari	'black ant'	(115)			

These words are not compounds (at least as far as is known) -- Snyman states (p.45) that he writes all compounds with a hyphen between the two roots.

The system of clicks in !Xũ is given in (38) (from Snyman p.50):

(38) <u>!Xũ</u> <u>Clicks</u>:

y	Dental		Alveolar			Lateral			Alveo-Palatal		
| |?	|x |x?	|h |?h	ǂ ǂ?	ǂx ǂx?	ǂh ǂ?h	ǁ ǁ?	ǁx ǁx?	ǁh ǁ?h	! !?	!x !x?	!h !?h
g|	g|Y g|Y?	 g|?h	gǂ	gǂY gǂY?	gǂh gǂ?h	gǁ	gǁY gǁY?	gǁh gǁ?h	g!	g!Y g!Y?	g!h g!?h
ŋ|		ŋ|h ŋ|?h	ŋǂ		ŋǂh ŋǂ?h	ŋǁ		ŋǁh ŋǁ?h	ŋ!		ŋ!h ŋ!?h
C	V	A	C	V	A	C	V	A	C	V	A

(As in Hottentot, di- and tri-graphs represent single segments.) The clicks in (38) are grouped according to influx: dental, alveolar, lateral, and alveo-palatal. These influxes are essentially identical to those of Hottentot; only the labels are slightly different. Ladefoged and Traill state: "as far as we can tell by careful listening and from comparisons of our data and those published by Beach, the clicks of Nama and !Xóõ (and most of the other related languages) do not differ significantly in their place of articulation" (p.24). Beach (1938) describes the Bushman clicks as identical to the Hottentot ones, and Snyman refers the reader to Beach for the phonetic description of !Xõ clicks. A slight difference is that, by Snyman's description, the dental and lateral releases in !Xõ are fricative, as opposed to affricative in Hottentot; however, as in Hottentot, the alveolar and alveo-palatal releases are stops. Thus, the degree of closure of the influx in !Xõ clicks is predictable by the same principles as predict the degrees of closure of the Hottentot influxes.

As for the effluxes, however, there are many more variations on the above four types of click in !Xõ than in Hottentot. Where the Korana dialect of Hottentot distinguishes six types of efflux, !Xõ distinguishes fourteen. Unlike in Hottentot, glottal and nasal features are not sufficient to distinguish all the click effluxes. Consider the !Xõ click effluxes in (39). I omit the voiced effluxes [g, gY, gh, gY?, g?h] because they differ from the voiceless effluxes [k, kx, kh, kx?, k?h] only in having the feature specification [+slack vocal cords, -stiff vocal cords].[16]

(39) <u>!Xũ Click Effluxes</u>

	k	kx	kh	k?	kx?	k?h		ŋ	ŋh	ŋ?h	
constr	-	-	-	+	+	+	-	-	-	+	-
spread	-	-	+	-	-	-	+	-	+	-	+
nasal	-	-	-	-	-	-		+	+	+	
	1	2	3	4	5	6		7	8	9	

The nasal and glottal features in (39) uniquely specify the aspirated efflux in column 3, the efflux with glottal stop followed by aspiration in column 6, and the three nasal effluxes in columns 7 through 9. However, the two unaspirated oral effluxes in columns 1 and 2, as well as the two glottalized effluxes in columns 4 and 5, are not yet uniquely specified. In each pair, one efflux is plosive and the other affricated. Unlike the affrication in Hottentot, this affrication of the velar release is not predictable in !Xũ. The existence of the aspirated efflux [kh] in column 3 precludes distinguishing the affricative efflux [kx] from the plain efflux [k] solely by the feature [+spread glottis], as was possible in Hottentot. Moreover, there is no phonetic evidence for classifying [kx] as [+spread glottis]. It is not aspirated, as was the affricated efflux in Hottentot. Similarly, the existence of the glottalized efflux [k?] in column 4 precludes deriving the affrication in [kx] from [+constr. glottis], for which there is no phonetic evidence anyway. Furthermore, the existence of

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16. Note that voicing is indicated by a "g" preceding the click. Thus, [!] is a voiceless alveo-palatal click, [g!] is a voiced alveo-palatal click. There is no additional velar closure in [g!] that does not exist in [!].

both [k?] and [kx?] effluxes shows that affrication is not predictable from [+constr. glottis]. Thus, in order to distinguish columns 1 and 2 and columns 4 and 5 in (39), it is necessary to add specifications for degree of closure, i.e. for the feature continuant, as in (40):

(40) <u>!XÕ Effluxes</u>:

	k	kx		kh	k?	kx?		k?h	
spread glottis	-	-		+	-	-		-	+
constr. glottis	-	-		-	+	+		+	-
continuant	-	-	+	-	-	-	+	-	

All the effluxes in (39) are therefore uniquely specified by the features [spread glottis], [constr. glottis], [nasal], and [cont].

Given that degree of closure is not distinctive for the coronal articulations in the clicks, it is possible to distinguish the velar articulations by degree of closure, as in (40), without using a special feature geometry with degree of closure for each articulator. The specification of [cont] in (40) is thus represented somewhere in the feature hierarchy outside of the place node. The problem now is how to indicate that the degree of closure should apply to the velar articulation and not to the coronal one.[17]

It is not possible to solve this problem in !XÕ by appealing to any

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17. One possibility might be to appeal to a principle that only effluxes, and not influxes, may contrast in degree of closure. But that would be begging the question somewhat, since it would require somehow knowing that the coronovelar constituted a click rather than a multiply-articulated explosive.

principle which would always apply degree of closure features to the velar articulation if there were more than one, because there exist complex segments in !Xũ in which the degree of closure does not apply to the velar articulation.

Consider the non-click obstruents in !Xũ (from Snyman p.35):

(41)

a. <u>!Xũ</u> <u>Non-Click</u> <u>Obstruents</u>

Labial		Alveolar		Post-Alv.		Velar	
p	ph	t	th			k	kh
b		d				g	gh
	b?h		d?h				g?h
		ȼ	ȼh	č	čh		
		ȼ?		č?		kx?	
		ɀ?	ɀ?h	ǰ?	ǰ?h		
		s		š		x	
		z		ž			h

b. <u>!Xũ</u> <u>Velarized</u> <u>Coronals</u>

Alv.	Post-Alv.
tx	
tx?	
dY	
ȼx	čx
ɀY	ǰY

As shown in (41b), to most of the coronals in !Xũ may be added what Snyman calls a "velar feature." Snyman does not describe the pronunciation of any of his consonant symbols, saying "it is taken for granted that the I.P.A. symbols ... will be sufficient definition of the !Xũ consonant sounds" (p.34). Thus, I take this "velar feature" represented by /x,Y/ at face value as a velar fricative. These coronals with "velar feature" are, then, complex segments: coronal plus velar, represented as in (42):[18]

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18. It is interesting that these occur in a language having coronal clicks, which are also coronal plus velar complex segments, and that only the coronals occur with velar feature, just as there are only coronal clicks. That is, it appears that !Xũ allows multiple articulator nodes under the place node only for the combination coronal plus dorsal, and disallows combinations of labial with coronal or labial with velar. It is common for

(42)
```
             place
             /   \
      coronal     \
                 dorsal
```

Thus, for !XŨ we need to represent the distinctions among [tx,ǂ,ǂx], that is, among an alveolar explosive with velar friction, an alveolar implosive with velar stop, and an alveolar implosive with velar affricate. The obvious solution is to distinguish these by degree of velar closure, as in (43) (represented centrally and interpreted as applying to the dorsal articulation by a means not yet chosen):

(43)

<table>
<tr><th></th><th>[tx]</th><th>[ǂ]</th><th colspan="2">[ǂx]</th></tr>
<tr><td>coronal</td><td>+</td><td>+</td><td colspan="2">+</td></tr>
<tr><td>dorsal</td><td>+</td><td>+</td><td colspan="2">+</td></tr>
<tr><td>cont</td><td>+</td><td>-</td><td>-</td><td>+</td></tr>
</table>

This solution cannot, however, incorporate the added distinction which needs to be made between these three and the coronal affricate with velar friction, [ȼx], which is like [tx] except that the coronal articulation must be [-cont][+cont].

While independent degrees of closure for each articulator would allow us to represent the distinctions among [tx, ȼ, ǂ, ǂx], I maintain that

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a language to restrict its complex segments in this way, by allowing only certain articulators to cooccur. Although the usual case is for a language, if it restricts the cooccurrence of articulators, to limit them to combinations of labial plus velar, that is not always the case. !XŨ, as we have seen, limits complex segments to the combination coronal plus velar. Margi, to be discussed below, limits its complex segments to labial plus coronal (for stop-stop combinations; it allows rounding of labials and velars, as well as coronals).

the need for these distinctions is still not evidence for independent degrees of closure for each articulator. To represent degrees of closure independently for each articulator in !Xõ would be to ignore important regularities in the data, and to predict that many more types of corono-velars should exist.

Consider the non-click consonants of !Xõ. Of the coronals, there may be stops, affricates, and fricatives. To either the stops or the affricates may be added a velar articulation. But the degree of closure of this velar articulation is predictable: it is always a fricative. Thus, taking the non-click consonants separately, we could represent the distinction between [tx] and [ȼx] with a single degree of closure specification which would be interpreted as applying to the coronal articulation:

(44) <u>Non-clicks:</u> <u>Degree of Closure Applies to Coronal Articulation</u>

	[tx]	[ȼx]	
coronal	+	+	
dorsal	+	+	
cont	-	-	+

This would allow the representation of the complex segments with a single degree of closure specification, and would capture the regularity that the velar articulation in the corono-velar non-clicks is always a fricative, since its degree of closure would be derived by rule.

Consider now the clicks. In these, as I argued for Hottentot, the degree of closure of the coronal articulation is entirely predictable, and it would be wrong to represent it phonologically. Therefore, the distinctions among the clicks, taken in isolation, could be represented with a single degree of closure specification, except that this one would be interpreted as applying to the dorsal articulation:

(45) <u>Clicks:</u> <u>Degree of Closure Applies to Dorsal Articulation</u>

<table>
<tr><th></th><th>[ǂ]</th><th colspan="2">[ǂx]</th></tr>
<tr><td>coronal</td><td>+</td><td colspan="2">+</td></tr>
<tr><td>dorsal</td><td>+</td><td colspan="2">+</td></tr>
<tr><td>cont</td><td>-</td><td>-</td><td>+</td></tr>
</table>

However, we cannot take the non-clicks and the clicks in isolation, and if we combine (44) and (45), we find that the first columns in each are identical, and that the second columns in each are also identical. The crucial difference between (44) and (45) is in which articulator the degree of closure features are interpreted as applying to, and this is not yet represented. Nevertheless, I maintain that important generalizations are captured by <u>not</u> representing degree of closure for each articulator. If degree of closure were represented for each articulator, then since coronal stops and affricates contrast among the non-click consonants, we would expect them also to contrast among the clicks. They do not. Also, since velar stops and affricates contrast among the clicks, we would expect them also to contrast among the non-click corono-velars. Again, they do not. Thus, representing degree of closure independently for each articulator predicts more types of corono-velar than actually occur.

If we don't represent degree of closure independently for each articulator, then what is needed is some way of representing the fact that in the !Xũ non-clicks, the degree of closure specification refers to the coronal articulation, while in the clicks, the degree of closure specification refers to the dorsal articulation.

3.3 Major and Minor Articulators

The problem to be solved is this. In the complex segments of !Xõ and Margi, we have seen that the degree of closure of one of the articulations in each complex segment is predictable.[19] Call this articulator A. The degree of closure of the other articulation, articulator B, must be specified phonologically. We do not want to specify the degree of closure of articulator B on its own articulator node because that would make it impossible to assimilate place of articulation without simultaneously assimilating degree of closure. However, if we specify degree of closure anywhere else but on the relevant articulator node, we are faced with the problem of representing the fact that degree of closure features apply to articulator B and not to articulator A. How can we make a single, central degree of closure specification apply to a particular articulator?

To solve this problem, I will adapt some ideas of Anderson (1976), in which he argues that in every multiply-articulated segment, one and only one articulation is considered primary; and also that the primary vs. secondary status of the articulations in a multiply-articulated segment is not phonetically determined, but rather may be revealed "only inferentially

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19. In those of Hottentot, the degrees of closure of both articulators are predictable.

through the relation of a sound to others in the system of the language in which it plays a part" (p.17). Primaryness, then, is a phonological, abstract property, not a phonetic one. Phonetically identical multiply-articulated segments may differ in respect to which of their articulations is primary. Anderson deals specifically with segments in which both articulations are phonetically of the same degree, arguing that "the traditional distinction of primary and secondary articlation is valid even for [these] segments" (p.17). For multiply-articulated segments in which one occlusion is of greater degree than the other(s), Anderson seems to accept the criterion that "when a sound involves two or more distinct constrictions, the most radical ... is the primary articulation, and the others are secondary" (p.19).

What I will adopt from Anderson's proposal is the idea that not all the articulations in a multiply-articulated segment have the same status phonologically. This is not, of course, an entirely new idea. A distinction between primary and secondary articulations has always been recognized. However, the traditional use of the primary/secondary distinction has been rather vague. It has always been somewhat unclear exactly what it means for one articulation to be primary and for another to be secondary.

In fact, the one point which has seemed the most certain about what it means for an articulation to be primary, that the primary articulation is the most radical constriction in the segment, and that secondary constrictions are always less radical than primary ones, is not correct. First, Anderson argues that a secondary articulation may have degree of closure equal to that of the primary articulation. Moreover, if we take the labiocoronal series in Margi to have primary coronal articulation (because of distinctive degree of closure) and secondary labial articulation (because of non-distinctive degree of closure), then in Margi /ps/ it is the less radical coronal articulation /s/ which is the primary one. Similarly, as I will demonstrate below, the velar articulation in Kinyarwanda /skw/ is secondary, despite its being the most radical constriction in the segment. In a segment with more than one articulator, therefore, the primaryness of the articulators cannot be predicted from their degrees of closure.[20] Rather, primaryness is an unpredictable property which must be phonologically specified.

Another proposal regarding the primary/secondary distinction has been that it is the primary articulation, and not the secondary one, that spreads its place features onto another segment in processes of place assimilation. For example, Chomsky and Halle argue that the velar articulation in Kpelle [kp] is primary because, they say, a nasal will become [ŋ] rather than [m] when it assimilates to [kp]. However, it is simply not true that Kpelle nasals become [ŋ] before [kp]. Welmers (1974) states that "before doubly articlated stops, nasals also have double articulation, [mŋ]. ... The choice between /mkp,mgb/ and /ŋkp,ŋgb/ ... may be arbitrary. I have personally preferred /ŋkp,ŋgb/ ... but again no great theoretical issue is at stake" (p.65). Thus, it is clear that where

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20. Even if it were predictable from the degree of closure which articulation were primary, our problem would not be solved, because there would still be the question of how the degrees of closure of the articlators were determined in the first place.

Welmers writes "ŋkp" in Kpelle /ŋkpiŋ/ 'myself', he is referring to phonetic [mŋkp], i.e. [mŋkpiŋ]. Anderson cites, in addition to Kpelle, nasal assimilation in Yoruba as resulting in [ŋ] before labiovelars, which "again indicates the primary character of the velar occlusion" (p.23). However, as with Kpelle, sources on Yoruba indicate that nasals assimilate to both articulations of a labiovelar. Bamgbose ((1967:165), for example, shows [ŋm] before /gb/: /ó ḿ gbó/ -> [ó ŋḿ gbó] 'he is hearing'. That the very cases that have been proposed to show place assimilation as a diagnostic for primaryness instead show both the articulations spreading in place assimilation is evidence that place assimilation has nothing to do with primaryness of articulations.

Thus, I have shown that the property of "primaryness" does not correspond to the traditional, non-technical usage of the term primary in that it does not correlate with the most radical constriction in a segment, nor does it determine what features will spread in place assimilation. What, then, does it mean for one articulation to be singled out as primary in a segment? Based on the data from !Xũ and Margi, in which in every complex segment there is one articulator with distinctive degree of closure and one with non-distinctive degree of closure, I propose that the primary/secondary distinction is what distinguishes between articulations with distinctive degree of closure and those with non-distinctive degree of closure. In short, what it means for an articulation to be "primary" in a segment is that it is the articulator to which the degree of closure features of the segment apply. To avoid confusion with the traditional, somewhat vague, and often erroneous, use of the primary/secondary distinction, I will call the property of being an articulator with distinctive degree of closure, i.e. being an articulator to which the single, central degree of closure specification in the segment applies, being a "major" articulator, defined in (46):

(46) <u>Major Articulator</u>
A major articulator in a segment is an articulator to which the phonological degree of closure features of the segment apply.

This has the effect that only a major articulation may be distinctively specified for degree of closure; the degree of closure of minor articulations will always be predictable <u>within a particular language</u>.

Thus, we may represent !XÕ clicks as having both coronal and dorsal articulations, of which the dorsal articulation is major in the sense of (46) and has distinctive degree of closure, while the coronal articulation is minor and has non-distinctive, predictable degree of closure. Similarly, the Margi labiocoronals have both labial and coronal articulations, of which the coronal articulation is the major one and has distinctive degree of closure, while the labial articulation is minor and has predictable degree of closure.

How may we represent the distinction between "major" and "minor" articulations? Anderson represents the distinction between primary and secondary articulations by a clever use of the feature [anterior]. Taking [anterior] literally to refer to the location of the "primary constriction in the vocal tract," Anderson proposes that a [kp] in which the labial closure is phonologically primary is [+anterior], while a phonetically identical [kp] in which the velar closure is phonologically primary is

[-anterior]. However, the feature [anterior] has been recently reinterpreted in such a manner that Anderson's use of it no longer is possible: Steriade (1986) argues that [anterior] is a feature distinctive only among coronals, and places it in the feature hierarchy under the coronal articulator node, as discussed in Chapter Two. Furthermore, in complex segments involving both labial and coronal closures (e.g. Kinyarwanda [tkw], Margi [ps]), both would be in Anderson's system [+anterior] if either of them were. Anderson's use of anterior could not pick out just one of them as primary (or major) (as /t/ is in [tkw] and /s/ is in [ps]).

How, then, should we represent the major/minor distinction? First, we can establish that being the major articulator cannot be a property of the articulator in isolation. For example, suppose we designated an articulator node in a segment as the major one by marking it with a "*" as in (47), where * is defined as attracting the closure features of the segment it occurs in. In (47a), then, the labial articulation would be major, while in (47b), the dorsal would be major:

```
(47)    a.      place                  b.      place
                /   \                          /   \
          labial*   dorsal               labial   dorsal*
```

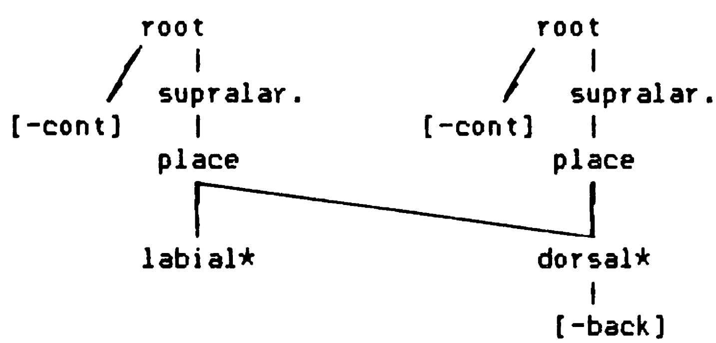
Thus, in (47a), a central degree of closure specification would be be applied to the labial closure, and the dorsal closure would receive a predictable degree of closure (within the language). In (47b), the degree of closure specification would be applied to the dorsal closure, the labial receiving predictable degree of closure.

3.3 Major and Minor Articulators

The problem with marking on the articulator itself the property of being the major articulator, as in (47), is similar to the problem with marking degree of closure on the articulator itself. Just as marking degree of closure features on the articulator and requiring them to spread with that articulator wrongly predicts that place assimilation will always result in assimilation of degree of closure, too, with the assimilated place features retaining their original degree of closure; so will marking majorness on the articulator in such a way that it spreads with the articulator, as in (47), wrongly predict that in every case of place assimilation, including assimilations like palatalization and labialization which add rather than replace place features, the new articulator will take on the degree of closure of the segment it spreads to, predicting all labializations of stops to result in labial stops, etc. Rather, being the major articulator has to be something that will not spread with an articulator, because a consonant may assimilate place features from a vowel without assimilating the property of being a major articulator that those features have within the vowel.

Consider, for example, a hypothetical example of palatalization before a high front vowel: /p/ + /i/ --> [pyi]. If being the major articulator were marked on the articulators, this palatalization would be as in (48).

(48)



In (48), the segment on the left is specified as [-cont] with two major articulators, labial and dorsal; this is the representation of the doubly articulated stop [pc], not of the palatalized labial [py]. The problem is that the * on the dorsal node attracts, not only the vowel features of /i/, but also the [-cont] of /p/, predicting not [pyi] but [pci]. We cannot solve this problem by deleting the * on the dorsal node, however, because it needs to be there for the vowel to assign its manner features to the dorsal articulator.

Rather, the property of being a major articulator is a relation between an articulator and the node the closure features are attached to, e.g. the root node.[21] Thus, only if the entire root node spreads will an articulator's being a major articulator spread. If just the supralaryngeal, place, or articulator node spreads, then all the features under that node will be equal in the segment the node is spread to. Since being a major articulator is a relation between the root node and an articulator node, I represent it as a pointer between the root and the major articulator, as in (49), where this pointer means nothing more than to apply the closure features specified at the root to the articulator that

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21. It cannot be a relation between the articulator and the closure features directly, because then if those closure features were deleted or spread, the articulator's property of being the major articulator would be deleted or spread, and this does not occur (see the analysis of Fula, below). Also, it would require the articulator to link to both [-cont] and [+cont] in an affricate separately.

the pointer points to:

(49)

```
Margi [pt]      root                    !Xõ  [ǂ]          root
               / |                                       / |
              /  supralar.                              /  supralar.
       [-cont]   |                               [-cont]   |
                 place                                     place
                 |  \                                      |  \
            labial   \                               coronal   \
                  coronal                                   dorsal
```

Some basic assumptions of this view of major articulators are as follows: In eve.y segment, the root node "points" to an articulator to mark which one the closure features apply to. (It may point to one or more than one.) If there is only one articulator node in the segment, then default rules will make the root node point to that articulator. Also, if there is more than one articulator, language-specific (or universal) default rules may set up the pointers. Rarely, a language will contrast two otherwise identical complex segments solely by which articulator is major (cf. the discussion of Fula /w/ below). In such a case, the pointers will have to be lexically specified. Finally, if as the result of some process, the root node loses its pointer (e.g. if the articulator node or the place node containing the articulator is deleted by place assimilation), it will reapply the redundancy rules to link to whatever articulator is there. As long as the root has a pointer, the redundancy rules will not apply. Thus, segments may be created by adding articulator nodes which are not major. In order for these to become major, a rule would have to apply to change or add the pointer (cf. some Shona dialects and Tswana, which seem to change the specification of major in their complex segments).

Given the above characterization of what a major articulation is, it can be seen why nasal assimilation, or place assimilation in general, is not a good diagnostic for determining the major articulator. In place assimilation, the entire place node spreads, with all the articulator nodes specified under it, regardless of whether they are major in the segment or not. Being the major articulator is concerned solely with the linking between closure features and articulator. It doesn't affect the representation of place features and articulator nodes.

Certain researchers have used the argument that one or the other articulation in a complex segment is primary (or major, in my terms) based on nasal assimilation facts. For example, Chomsky and Halle claim that [kp] in Kpelle has major velar articulation both because it functions as a velar in the sound system of the language and because nasals assimilate to [ŋ] rather than [m] before it. However, careful reading of the source on Kpelle used by Chomsky and Halle reveals that the [ŋ] before [kp] was orthographic only, and that phonetically, nasals before labiovelar [kp] assimilated both places of articulation, becoming labiovelar [mŋ]. Similarly, Anderson argues that Yoruba [kp] is primarily velar, based on distribution and on nasal assimilation, but sources again describe the nasal before [kp] as [mŋ], not simply [ŋ] (Bamgbose). Finally, we have seen that Margi [pt] involves a major coronal articulation; yet nasals become [mn] before [pt], not [n].

Another example which shows that it is not only the major articulation that is realized on preceding nasals is the following. Sherbro contains the partial inventory in (50) (Ladefoged p.47):

(50)	p	t	k
	b	d	gb
	mp		ŋkw
	mb	nd	mŋgb

The place of /gb/ in the system of Sherbro is clearly a voiced velar stop. Hence, it would be regarded by Anderson's or by Chomsky and Halle's arguments as having major velar articulation and minor labiality. However, note that the prenasalized form of /gb/ is not /ŋgb/ but /mŋgb/. Hence, even though the labial articulation is phonologically minor, it still assimilates. This is a consequence of it being represented under the place node equivalently to the velar articulation.

In the following subsections, I examine processes of labialization, labiovelarization, and palatalization in Nupe, Shona, and Kinyarwanda. The definition and representation of the major/minor distinction that I have argued for above makes possible straightforward predictions of the results of these processes in the various languages, which results are impossible to represent under either the traditional definition of primary/secondary or even with a representation allowing separate degrees of closure for each articulator.

3.3.1 Nupe

Nupe has the basic consonant inventory in (51) (from Hyman (1970)):

(51)

p	t			k	kp
b	d			g	gb
f	s		š		
v	z		ž		
	ȼ		č		
	ʣ		ǰ		
m	n				
	l,r				
w		y			

In addition, there are a labialized and a palatalized series. Any consonant may be labialized or palatalized. Labialized and palatalized consonants contrast with plain consonants only before /a/. Before /i,e/, labialized consonants do not occur and there is no contrast between palatalized and plain; before /u,o/, palatalized consonants do not occur, and there is no contrast between labialized and plain.

Hyman argues that the labialized and palatalized series are just that: single segments, rather than sequences of consonant plus glide. There are no other consonant clusters in the language, and the occurrence of glides after [kp,gb] would be especially problematic. In a survey of consonant systems in African languages, Welmers (1973) states: "the only case known to me of doubly articlated stops /kp,gb/ followed by a palatal or bilabial segment (or, for that matter, any comparable type of segment) and then a vowel is in Nupe; and even these have a peculiar status" (p.68). Thus, if we consider them single segments, we may eliminate the exceptional status of Nupe /kpw, kpy, gbw, gby/. Also, if Cw and Cy were sequences of consonant plus glide, the distribution of glides in Nupe would be very strange. Whereas most languages, if they have a restriction, disallow sequences of like vowel and glide, that is the only kind that Nupe allows before non-low vowels: it requires /w/ before /u/ and /y/ before /i/.

Thus, an analysis in which the labiality or palatality of the consonant is the result of assimilation to the following vowel makes much more sense. As for the Cw and Cy before /a/, Hyman argues that these are also derived by assimilation, to underlying [+low] /O/ and /E/, which vowels are then neutralized to /a/. Under Hyman's analysis, then, the underlying vowel inventory of Nupe is that in (52a), while the surface inventory is that in (52b):

(52)

a.

	i	e	E	a	O	o	u
high	+	-	-	-	-	-	+
low	-	-	+	+	+	-	-
back	-	-	-	+	+	+	+
round	-	-	-	-	+	+	+

b.

```
i       u
e       o
    a
```

All of the words with Cw and Cy before /a/ derive from earlier /CO/ and /CE/. Furthermore, the rules of labialization and palatalization before /O/ and /E/, and of neutralization of /O/ and /E/ to /a/, are still productive. Hyman cites recent borrowings from Yoruba into Nupe, which are subjected to palatalization, labialization, and neutralization:

(53)

Yoruba	[kEkE]	-->	Nupe	[kyakya]	'bicycle'	
	[EgbE]	-->		[egbya]	'a Yoruba town'	
	[tOrE]	-->		[twarya]	'to give a gift'	
	[kObO]	-->		[kwabwa]	'penny'	(p.66)

Hyman also states that "a Nupe speaker will consistently 'nativize' [CO] as [Cwa] and [CE] as [Cya] ... [which] is also sometimes perceptible in the way Nupes attempt to speak Yoruba, which has /O/ and /E/" (p.66).

The contrasts in Nupe whose representation concerns us in this section are the following:

(54)	labial	coronal	velar	labiovelar
plain	p	t	k	kp
palatalized	py	ty	ky	kpy
labialized	pw	tw	kw	kpw

As mentioned above, palatalized and labialized consonants are derived by the processes in (55a,b), which is followed by the neutralization in (55c).

(55) a. C --> Cy / ___ i,e,E

b. C --> Cw / ___ u,o,O

c. E,O --> a

The palatalized consonants are derived before the front vowels /i,e,E/, the labialized ones before the round (back) vowels /u,o,O/. We must represent this as a spreading of just the features [round] and [back], and not as either the articulator nodes or the place node, because /E,O/, after triggering palatalization and labialization, are neutralized to /a/. That is, the very features [round] and [back] that are spread onto the consonant are later delinked from the vowel, if it's low. If, as shown in (56) below, either the place node (56a) or the articulator node (56b) were spread, it would be impossible to either delink or change the values of the features [round] and [back] to create /a/ without simultaneously destroying the labialization or palatalization of the consonant. Also, spreading the dorsal node would entail spreading [+low] onto the consonant, which would be expected either to have an effect on the consonant's articulation, e.g.

pharyngealization, or to have a raising effect on the following vowel. Since no effects are created, [+low] isn't spread onto the consonant.

(56) tE --> tyE --> tya

```
a.      * supra  supra                b.    * place   place
            |  \   |                           /    \  /
        place  place                          /   dorsal
          /      |                      coronal     |
        cor     dorsal                            [-back]
                 |                                [+low ]
               [-back]
               [+low ]
```

Therefore, labialization and palatalization must be as in (57), a spreading of [round] and [back], with interpolation of the relevant articulator nodes if they don't yet exist. If the relevant articulator node already exists, the features will link to it.

```
(57)
place            place                   place            place
  |                | \                   /  |               |  \
labial         labial \         ==>     / labial         labial  \
                  /   dorsal        dorsal      \       /      dorsal
             [round]    |                       [round]           |
                     [back]                                     [back]
```

Now to derive the correct palatalized and labialized forms, assuming a spreading of [round] and [back]. Note that in the absence of any degree of closure information, there will be no distinction between [py] and [pky] or between [kw] and [pkw], as shown in (58).[22]

----

22. Hyman states that he assumes an additional suction feature in the [pk] forms in order to distinguish them. However, I have argued in chapter two that such suction features are unnecessary.

(58) a. [py] or [pky]

```
        place
        |    \
      labial  \
             dorsal
               |
             [-back]
```

b. [kw] or [pkw]

```
            place
            |    \
          labial  \
           /     dorsal
     [round]       |
                 [+back]
```

The reason for this lack of distinction is that the features [round] and [back] cannot be specified without specification of the articulator nodes labial and dorsal, respectively. That is, it is impossible to specify a segment as [+round] without also specifying it as labial, or to palatalize a segment (specify it as [-back]) without also specifying it as dorsal. This relation between features and articulator nodes has been argued for in the previous chapter. Were it not for this relation between features such as [round] and [back] and articulator features such as labial and dorsal, we could represent the distinctions among the segments in (58) as in (59):

(59)

	py	pky	kw	pkw
labial	+	+	-	+
round	-	-	+	+
dorsal	-	+	+	+
back	-	-	+	+

This is essentially the approach (although in terms of [anterior] instead of [dorsal]) taken by Hyman (1970) for Nupe, and by Chomsky and Halle (1968), Anderson (1976), and many others for similar problems.

But given the definitions of the features in (59) that were given in Chapter Two, it is simply a physical impossibiliy for an articulation to be [+round] and not labial, or [-back] and not dorsal. The feature characterizations in (59) are not an option here. Therefore, without appeal either to the classification in (59) or to separate degrees of closure for each articulator, we need somehow to distinguish [py] from [pky] (in (58a)), and [kw] from [pkw] (in (58b). That is, we need to represent the fact that in [py] the dorsal articulation is [+continuant, -consonantal], while in [pky] the dorsal articulation is [-continuant, +consonantal]. Similarly, we need to represent the fact that in [kw], the rounded labial articulation is [+continuant, -consonantal], while that in [kpw] is [-continuant, +consonantal]. The only difference between [py] and [pky] or between [kw] and [kpw] is the degree of closure of the dorsal or labial articulator, respectively.

It is clear that the degrees of closures of the articulators in labialized and palatalized segments depends on what the segment was prior to labialization or palatalization. If a [-cont] labial articulation was already there before adding [+round], then the labial articulation remains there as [-continuant]. If, however, there was no labial articulation before [+round] was added, then the labial articulation in the labialized segment is [-consonantal]. The labial node resulting from adding [+round] does not take on the [-cont] of the segment it is added to. Similarly, a dorsal articulation in a palatalized segment will be [-cont] only if there was a [-cont] dorsal articulation prior to palatalization. Dorsal nodes added by palatalization are [-consonantal].

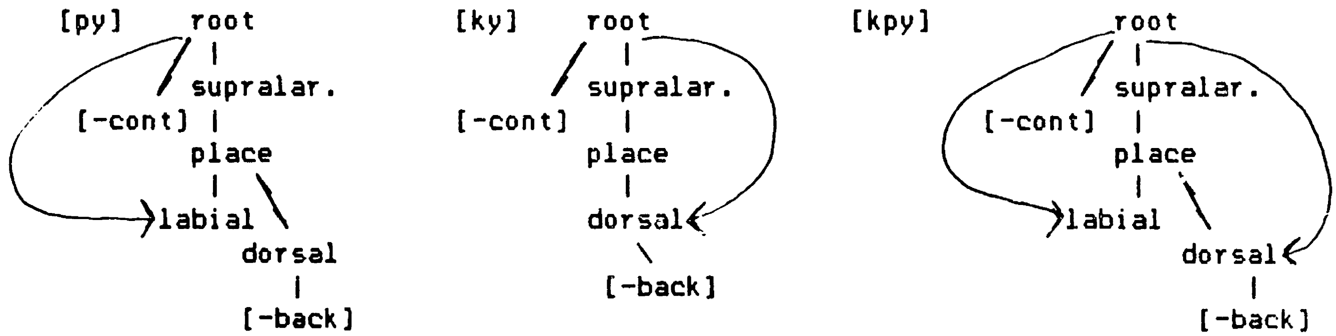
We cannot, however, base a distinction between [kw] and [pkw], or between [py] and [pky], simply in the origin of their labial and dorsal nodes. To resort to an explanation of this sort would be to incorporate global knowledge, information about the derivational history of the segment which is no longer contained in its representation, into its interpretation. Rather, what is needed is for there to be a representational difference between labialized /k/ and labialized /pk/ after rounding has applied, from which to derive the difference in the degree of closure features for [kw] and [kpw] after rounding has applied, and for [py] and [pky] after palatalization. Further, this representational difference must enable us to correctly derive the degree of closure features in each segment which results from rounding triggered by a round vowel or palatalization triggered by a front vowel.

We may accomplish all this, both representing the difference between [py,kw] and [pky,pkw] and correctly deriving the right complex segments by palatalization or labialization, by specifying different articulators as major, as in (60):

(60)

```
[p]      root            [k]      root            [kp]     root
        / |                      / |                      / |
       /  supralar.             /  supralar.             /  supralar.
[-cont]   |              [-cont]   |              [-cont]   |
          place                    place                    place
          |                          \                      |    \
     labial                           dorsal            labial    dorsal
--------------------------------------------------------------------------
[pw]     root            [kw]     root            [kpw]           root
        / |                      / |                             / |
       /  supralar.             /  supralar.                    /  supralar.
 [-cont]  |              [-cont]   |                     [-cont]   |
          place                    place                           place
          |  \                     |  \                            |   \
     labial   \               labial   \                      labial    \
      /      dorsal            /      dorsal                   /       dorsal
 [+round]      |          [+round]      |                 [+round]        |
            [+back]                  [+back]                           [+back]
--------------------------------------------------------------------------
```

3.3 Major and Minor Articulators



In [kp], both labial and dorsal must start out as major. If labial weren't major, we couldn't distinguish [kw] and [kpw]. If dorsal weren't major, we couldn't distinguish [py] and [kpy]. ¶ In (60), a pointer to an articulator means that the degree of closure features of the segment apply to it. Therefore, having marked both articulators as major in [kp] requires that both have the same degree of closure, which they do. There is no prohibition against more than one articulator being marked to take the degree of closure features. That is probably what rounded vowels are like. However, a complex segment may only have both marked if they agree in degree of closure. In a complex segment in which the closures vary in degree, as in Margi labiocoronals, Kinyarwanda, clicks, etc., only one of the closures may be major and receive the degree of closure specification of the segment. The other's degree of closure will be predictable. In short, there can be only one (simultaneous) distinctive degree of closure specified in any segment.[23] That specification may apply to both articulators equally, or it may apply only to one of them. There will exist no complex segments in which the degrees of closures of both

----

23. The [-cont][+cont] of an affricate counts as a single distinctive degree of closure specification because it applies to a single articulator. What is excluded is, e.g., [-cont] for the labial articulator and [+cont] for the dorsal articulator in the same segment.

articulators are unequal and unpredicable (distinctive).

3.3.2 Shona

The consonants of Shona "seem at first sight to present an almost insoluble jig-saw puzzle in their variety and permutations" (Doke (1931:36)). Nevertheless, the theory of phonology and phonetics I have developed in this chapter and the previous one -- specifically a feature structure with independent nodes for each articulator and with a means of marking which articulators are major for the purposes of assigning degree of closure features -- makes possible a straightforward solution to the "jig-saw puzzle" of Shona consonants.

In Shona, as in Nupe, there is a process of labiovelarization of consonants which adds minor articulations of velarity and labiality. However, unlike Nupe, in which the minor articulations are always [-consonantal] in degree, in Shona a minor articulation may become a fricative [-son,+cont] or even a stop [-cont]. There is considerable variation both across and within dialects in the degrees of closure of the minor articulations added by labiovelarization in Shona.

I will start by examining a typical pattern of labiovelarization in Shona, that found in the Zezuru dialect of Central Shona, shown in (61).

(61) Zezuru Consonants

Single POA				Labiovelarized			
p	t		k	pk ~ px ~ pɷ	tkw ~ txw		kw
b	d		g	bg ~ bY	dYw		gw
mb	nd		ŋg	mbg ~ mb̈Y	ndYw		ŋgw
m	n	ň	ŋ	mŋ ~ mɷ̈	nŋw	ňŋ ~ ňŋw	ŋw
pf	ȼ	č			ȼkw	čk ~ čkw	
bv	ɉ	ǰ			ɉgw ~ ɉYw	ǰg ~ ǰgw ~ jYw ňǰYw	
f	s	š			skw ~ sxw	škw	
(B)	z	ž			zgw ~ zYw	žgw ~ žYw	
	nz				nzYw		
	r,l				rYw ~ rw		

Labialized Alveolars	Labiovelarized Labialized Alveolars	
ć		
ʝ		
ś		şkw ~ şw[24]
ź		ȥgw ~ ȥYw

Data illustrating some of the free variation in degree of closure in labiovelarized consonants in Zezuru are given in (62) (followed by the page numbers where they occur in Doke):

----

24. Note that the labialized alveolars [ȥ, ş] are not the same as [zw], [sw]; furthermore, [ȥ, ş] may themselves be followed by [w] (labialized?), according to Doke (p.86). Thus, there is a four-way contrast among: [s], [ş], [sw], [şw]. Nevertheless, for some forms, there is variation among the dialects between [ş, ȥ] and [sxw], [zYw], as might be expected given their close phonetic similarity:

Manyika [ruşişi]	Zezuru [rusxwisxwi]	'young grass'	(p.88)
Korekore [kunȥa]	Zezuru [kunzYwa], Manyika [kunzwa]	'to hear'	(p.89)

(62)

/p/	hapxa	~	hapka		'armpit'	(111)
	pkere	~	pŋʷere	~ pxere	'child'	(110)
/m/	mŋana	~	mŋʷana		'child'	(112)
	kujamŋw	~	kujamŋʷa		'to suck'	(112)
	šamŋari	~	šamŋʷari		'friend'	(112)
/s/	skwiña	~	sxwiña		'pinch'	(116)
	iskwa	~	isxwa		'be placed' (/is-wa/)	(116)
/ǰ/	ŋgaǰɣwa	~	ŋgaǰgwa		'be bound'	(118)
	kukuǰɣwa	~	kukuǰgwa		'be renowned'	(118)
/z̧/	kwez̧ɣwa				'be attracted'	(118)
	rez̧gwa				'be lulled to sleep'	(118)
/ʒ/	kuti ʒgwererere				'cry of birds'	(119)
	kuti ʒɣwe				'to be pale'	(119)

One of the facts to be accounted for here is that while there is much variation in the degree of velar closure in the labial, alveolar, and palatoalveolar labiovelarized consonants, there is no variation at all in the degree of velar closure in the velar labiovelarized consonants. Our account must differentiate between those velar closures that vary and those that don't. Another aspect of the data to be accounted for is the deletion of [+round] in the labial labiovelarized consonants, in contrast to the alveolar, palatoalveolar, and velar labiovelarized consonants, which for the most part do not delete [+round]. In particular, a crucial distinction must be made between [pk] ~ [px] derived from /p/ and [kw] derived from /k/. In the former, [+round] must be deleted and the velar closure is variable, while in the latter [+round] is not deleted and the velar closure is unchanging. Yet in terms of place features, labiovelarized /p/ and /k/ are identical:

```
(63)     place
         /   \
    labial   dorsal
     /           \
  [+round]     [+back]
```

Without a way of further distinguishing labiovelarized /p/ and /k/, it would be impossible to predict whether [+round] should delete in (63); whether the labial articulation should be [-consonantal] or [+consonantal,-cont]; or whether the dorsal articulation should remain [-cont] or be allowed to vary in degree of closure. However, with a means of marking one articulation as major (meaning simply that it receives the degree of closure features of the segment), distinguishing labiovelarized /p/ and /k/ and predicting their correct phonetic forms is straightforwardly accomplished.

The derivation of labiovelarized /p/ and /k/ is shown in (64a,b), respectively:

```
(64)
a.  /p/                                                  [pɸ] ~ [px] ~ [pk]

    root                   root                      root
     |   \                  |   \                     |   \
   supra [-cont]          supra [-cont]             supra [-cont]
     |             ==>      |              ==>        |
   place                  place                     place
     |                    /   \                     /   \
   labial             labial   dorsal          labial   dorsal
                       /          \                        \
                   [+round]     [+back]                  [+back]
```

```
b.      /k/                          [kw]

        root                         root
       / |                          /  |
[-cont] supra      ==>       [-cont] supra
         |                            |
        place                        place
         |                           /   \
        dorsal                   labial   dorsal
                                 /           \
                            [+round]       [+back]
```

In (64a), [+round] is deleted from a major labial articulator node; it is not deleted in (64b) because the labial articulator node is not major. Language-specific phonetic interpretation rules will interpret the minor dorsal articulation in (64a), which is not phonologically specified for degree of closure, as anywhere from [-consonantal] [w], to [+consonantal,+cont] [x], or even [-cont] [k]. The dorsal articulation in (64b), however, is phonologically specified as [-cont], since it is the major articulation and receives the phonological degree of closure features. Hence there is no variation in the degree of closure of the dorsal articulation in (64b). The degree of closure of the minor labial articulation in (64b) is not governed by any language-specific rule; therefore, it will be interpreted, as in Nupe, as [-consonantal], the universal default for minor articulations. To enable the representation of these phonetic degrees of closure for minor articulators, the feature geometry at the level of phonetic representation will differ from the geometry I have proposed for phonological representation. The representations required for the outputs of these phonetic interpretation rules are discussed in Chapter Six.

The above account of the differences between labiovelarized /p/ and

/k/, with no further provisions, also derives correctly the phonetic output of labiovelarizing a coronal. Consider the derivation of /t/ into [tkw] ~ [txw] in (65):

```
(65)    /t/                          [tkw] ~ [txw]

        root                              root
       / |                               /  |
[-cont] supra                   [-cont] supra
         |              ==>               |
        place                            place
         |                               / | \
        coronal                    labial  |  coronal
                                      /  dors.
                               [+round]    |
                                        [+back]
```

In (65), both the labial and the dorsal articulations are minor. Thus, the labial articulation remains [+round] just as in [kw] in (64b) above, while the dorsal articulation varies in degree of closure just as in (64a) above. Nothing further need be said. This account also correctly derives the phonetic form of labiovelarized /s/, which is identical to that of /t/ in (65) above except that /s/ would have the specification [+cont]. The degree of closure of the dorsal articulation is unrelated to the phonological degree of closure of the segment it occurs in. Thus, even in the phonologically [+cont] segment /s/, the phonetic interpretation rules may create a [-cont] [k], yielding [skw]. This, then, is an example where the major articulation is less radical than the minor one, which shows that the notion "major" is properly characterized as an abstract, phonological property relating degree of closure features to a particular articulator, and is not the phonetic property of being the "most radical" articulation, nor the pretheoretic, intuitive notion of being in some way psychologically prominent.

3.3 Major and Minor Articulators

To summarize, we may characterize the difference between Nupe and Shona by adding an optional and variable process in the phonology of Shona to strengthen the minor dorsal articulation in a complex segment to a fricative or stop, as well as a process delinking [+round] from major labial articulations. Further data from other Shona dialects showing the variation in degree of closure in minor dorsal articulations are given in (66) – (67) (followed by the page where they occur in Doke):[25]

(66) CENTRAL SHONA

Korekore	kujamŋwa	~	kujamwa	'to suck'	(112)
Manyika	mŋana	~	mɰana	'child'	(112)
	mŋojo			'heart'	(112)
	m͡ŋija			'strength'	(112)
				(m͡ŋ = click)	
Tavara	hapwa	~	hapɰa	'armpit'	(111)
	pxira	~	pɰ̥ira	'dry up'	(111)

(67) EASTERN SHONA

Ndau	mŋana (one speaker had [mwana])			'child'	(161)
	k'upxisa			'to make dry up'	(160)
	mundwere	~	mundYwere	'species of insect'	(161)
	rasxwa	~	rasɰ̥a	'be lost'	(163)
Tonga	m͡ŋana			'child'	(161)
	k'um͡ŋa			'to drink'	(161)
	mwaruŋgu			'sugar cane'	(161)
	mweɲɟe			'grass'	(161)
Danda	m͡ŋananini			'child'	(161)
	k'um͡ŋa			'to drink'	(161)
Teve	mɰana			'child'	(161)
	kuamɰa			'to suck'	(161)
	imɰimɰi			'you'	(161)
	kumwa			'to drink'	(161)

----

25. [m͡ŋ] here represents a nasal click.

3.3 Major and Minor Articulators

Eanga	mω̃ana	'child'	(161)
	kupxa	'to dry up'	(160)
	həpka	'armpit'	(160)
	imbYa	'dog'	(160)
	kumω̃a	'to drink'	(161)
	mau§wa	'grass'	(163)

"In Western Shona, velarization is not nearly so prominent a feature as it is in the Central dialects. It occurs only with bilabial consonants, and even with them seems to be avoided in Lilima. In Rozi, when used with bilabials, it was noticed to be accompanied by the semi-vowel -- a very rare occurrence."

(68) WESTERN SHONA (pp.186-87) (Nambzya)

hapxja	~	apω̂a	'armpit'	(cf. Kalanga hapxa)
kupxja	~	kupω̂a	'to dry up'	(cf. Kalanga kupxa)
bYjato	~	bω̂ato	'canoe'	
ibYje	~	ibω̂e	'stone'	(cf. Kalanga bYe)
imbYjə	~	imbω̂a	'dog'	(cf. Kalanga mbYa)
kumŋa	~	kumω̃a	'to suck'	(cf. Kalanga kumŋa)
imŋi	~	imω̃i	'you'	(cf. Kalanga imŋi)

The Urungwe dialect of Korekore (Central Shona) avoids combination of velarization with bilabials; in cases where Korekore in general has velarized labials, Urungwe instead substitutes the labialized velars [xw, Yw, ngw]. For example:

(69)

Urungwe Korekore:	Korekore:		
ixwa	ipxa	'sweet reed'	(110)
iŋgwa	imbwa ~ imbwa ~ imbYa	'dog'	(111)
xwere	pxere	'child'	(110)

I characterize this as follows. It is common in Shona (and in Kinyarwanda, discussed in the next section) for labiovelarized labials not to surface as rounded, but to surface instead with just velarization, e.g. corresponding to labiovelarized [tkw] there will be velarized [pk], without rounding. In my terms, these languages avoid the specification of [+round] on a major labial articulator node, although [+round] on a minor labial node is fine, as in [tkw] or [kw]. I suggested above that one of these languages, Zezuru, deals with the ill-formed (in that language) structure (70a) below by delinking the [+round], yielding (70b). In Urungwe, however, the ill-formed structure (70a) is converted to (70c) by changing the specification of major from the labial to the dorsal node. The specification of [+round] on the labial node is then allowed, since the labial node is not major. Changing the major specification from the labial node to the dorsal node has the automatic consequence that the formerly [-cont] labial /p/ becomes [-consonantal]. When the labial node was major, it received the phonological degree of closure features of the segment; it automatically loses those and is interpreted by universal redundancy rules when it loses the major specification.

```
(70)    a.  *[pkw]                 b.  [pk]                  c.  [kw]

                *root                      root                      root
                 / |                       / |                       / |
          [-cont] supra             [-cont] supra             [-cont] supra
                   |                         |                         |
                  place                     place                     place
                  /  \                      /  \                      /  \
             labial dorsal             labial dorsal             labial dorsal
               |                                                   |
            [+round]                                            [+round]
```

The prediction is also that the dorsal articulation, previously [+cont] by phonetic interpretation but unspecified for phonological degree of closure, should automatically take on the [-cont] phonological degree of closure that used to apply to /p/. While this prediction is not borne out in Urungwe Korekore, where the dorsal articulation remains [+cont] (as shown in (69)), it is borne out in the Western Shona dialect of Lilima, in which this same process, changing the major specification from labial to dorsal when the labial node dominates [+round], occurs. Examples are given in (71) (from Doke (p.186,Appendix IV p.b)), contrasted with cognate forms in the closely related Western Shona dialect Kalanga:

(71)

Lilima:	kukhwa	Kalanga:	kupxa	'dry up'
	hakhwa		hapxa	'armpit'
	gwilila		bYiɭila	'return'
	gwe		bYe	'stone'
	ŋgwa		mbYa	'dog'
	kuŋwa		kumŋa	'to suck'
	iŋwi		imŋi	'you'
	ŋwana		mŋana	'child'

3.3.3 Kinyarwanda

The results of labiovelarization in Kinyarwanda are similar to those I have just discussed for Shona, to which Kinyarwanda is related as a Bantu language. Kinyarwanda in addition contains a process of palatalization whose results parallel the results of labiovelarization.

Kinyarwanda has no underlying complex segments. Consonants are palatalized (72a) and labiovelarized (72b) before unsyllabified [-low] vowels, with compensatory lengthening of the following vowel, as discussed in Chapter Two:

```
(72) a.   σ            σ            b.       σ             σ
         / \          / \                   / \           / \
        O   R   ==>  O   R                 O   R   ==>   O   R
        |   |        |  /|                 |   |         |  /|
        x x x        x x x                 x x x         x x x
        | | |        |  \|                 | | |         |  \|
        C i V        Cy  V                 C u V         Cw  V
          e                                  o
```

To review, Kinyarwanda allows branching rimes only for long vowels. In any sequence of a consonant followed by two unlike vowels, the first vowel will fail to syllabify and the second vowel will take the consonant as its onset, as shown in (72). If [-low], the unsyllabified vowel will then labiovelarize or palatalize the preceding consonant. Regardless of the height of the unsyllabified vowel, the second vowel will lengthen by spreading onto the x-slot of the first vowel.

The labialized and palatalized consonants in Kinyarwanda pattern as in the partial list in (73):

(73)	p	s	t	k
	pc	sc	tc	c
	pk	skw	tkw	kw

Despite their apparent differences, the labialized and palatalized consonants in Kinyarwanda may be derived exactly as those in Nupe, that is, by the spreading of [round] and [back] onto the consonant, with the underlying specification of the major articulator determining the phonetic output. The only difference is that in Kinyarwanda, as in Shona, there are the additional processes of velar fortition and of delinking [round] from major labial articulations.

Distinguishing a major articulator is necessary in Kinyarwanda in order to derive correctly the labiovelarized forms of /p/ and /k/. If /p/ and /k/ were not marked prior to labiovelarization as having major labial and dorsal articulators, respectively, then there would afterwards be no distinction between them, both [pk] and [kw] being represented as (74):

3.3 Major and Minor Articulators

(74)

```
              root
             /  |
            /  supralar.
      [-cont]   |
               place
               / \
          labial  \
             |   dorsal
        [+round]   \
                  [+back]
```

Not having access to the origin of (74) as either /p/ or /k/ (because to have such access would be to incorporate global knowledge into the grammar), there is no way to differentiate it into [pk] and [kw], e.g. by deleting [+round] for [pk] or by somehow specifying the labial articulation as [-cons] for [kw]. If, however, /p/ and /k/ are marked prior to labiovelarization as having major labial and dorsal articulations, respectively, then the derivation can proceed as in (75a) for [pk] and as in (75b) for [kw]:

(75)

```
a.       [-cont]              [-cont]              [-cont]
          /                    /                    /
       root                 root                 root
        |                    |                    |
       supralar.   ==>      supralar.   ==>      supralar.
        |                    |                    |
       place                place                place
        /                    / \                  / \
      labial               labial \             labial \
                             |   dorsal                dorsal
                         [+round]  \                      \
                                  [+back]               [+back]
--------------------------------------------------------------------
```

```
b.        [-cont]                    [-cont]
            /                          /
        root                       root
          |                          |
        supralar.      ==>         supralar.
          |                          |
        place                      place
          |                         / \
        dorsal                 labial   \
                                  |    dorsal
                             [+round]    \
                                       [+back]
```

In (75), it is possible to derive [pk] by delinking [+round] from a major labial articulator node, without affecting [+round] in [kw] because that labial node is not major. The velar fortition process will make the (minor) dorsal articulation in (75a) [-cont]. This process does not apply in (75b) because the velar articulation is major there. The minor labial articulator in (75b) is interpreted phonetically as [-cons] by universal default rules.

Most interesting of all is the derivation of [skw]:

(76)

```
               [+cont]                    [+cont]
                 /                          /
             root                       root
               |                          |
             supralar.      ==>         supralar.
               |                          |
             place                      place
               |                        / |  \
             coronal                   /  lab  \
                                coronal   |   dorsal
                                        [+rd]    \
                                               [+back]
```

In (76), minor articulations of labial and dorsal are added to /s/. As usual, the labial is interpreted as [-cons] and the dorsal as [-cont]. In this case, however, that makes the minor dorsal articulation the most radical of the three. This is evidence that being the major articulator is a purely abstract, phonological property defined as being the articulator which takes the degree of closure features of the segment, and that it is not a property that is phonetically predictable as belonging to "the most radical constriction" or to "the closure closest to the glottis", as proposed by Ladefoged (cited in Hyman), for both of these fail in Kinyarwanda [skw].

Evidence that it is correct to spread just [round] and [back] in Kinyarwanda labiovelarization and palatalization, as I have done above, rather than spreading the entire place node or the articulator nodes, comes from the interaction of these processes with vowel harmony. In Kinyarwanda, suffixes with non-low vowels surface with either [+high] or [-high] variants depending on the height of the stem vowel. Examples of vowel harmony (from Sibomana (1974:27-29); Kimenyi (1978)) are:

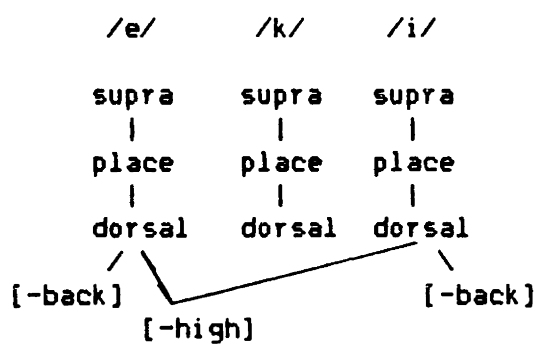
(77)

/ku-sig-a/	[gusiga]	'hinterlassen'	/ku-sig-ir-a/	[gusigira]	'hinterlassen für'
/ku-suk-a/	[gusuka]	'giessen'	/ku-suk-iir-a/	[gusukiira]	'lange giessen'
/ku-sek-a/	[guseka]	'to laugh'	/ku-sek-ir-a/	[gusekera]	'to laugh at'
/ku-kor-a/	[gukora]	'to work'	/ku-kor-ir-a/	[gukorera]	'to work for'

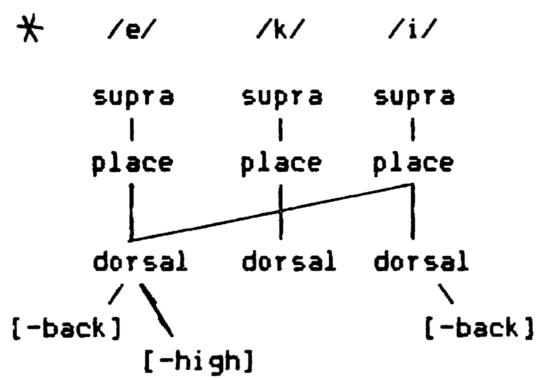
Vowel harmony may be characterized as the spreading of [a high] from the root to a [-low] suffix vowel. Backness and roundness are unaffected, so it must be just the feature [high], and not the dorsal articulator node or the place node, that spreads. Further evidence that it is just the feature [high] that spreads is the fact that intervening consonants, even do /k/, do not interfere with harmony. Spreading of the place node or of the dorsal articulator node would be blocked by an intervening /k/; only spreading of [high] will work. This is shown by the derivation of height harmony in [gusekera] (see (77b)), illustrated in (78).

(78)

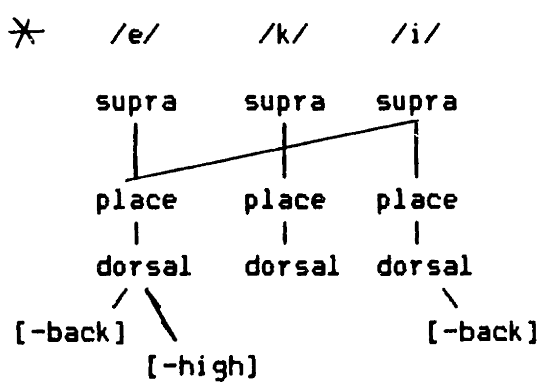
a. spreading [high]



b. spreading dorsal



c. spreading place



With stems of the form CV before V-initial suffixes, where both V's are [-low], the environments for both palatalization/ labiovelarization (with compensatory lengthening of the suffix vowel) and vowel harmony are met. If the stem is Cu or Co, both labiovelarization and harmony apply, as in (79):[26]

(79)

a.	/ku-gu-a/	[kugwa]	'to fall'	/ku-gu-ir-a/	[kugwiira]	'to fall on'
b.	/ku-ko-a/	[gukwa]	'to give bride-wealth'	/ku-ko-ir-a/	[gukweera]	'to give bride-wealth for'
	/ku-no-a/	[kunŋwa]	'to drink'	/ku-no-ir-a/	[kunŋweera]	'to drink for'

If, however, the stem is Ci or Ce, only harmony applies. The palatalization whose environment is met does not occur (although compensatory lengthening apparently does occur).

(80)

/ku-gi-a/	[kugya]	'to go'	/ku-gi-ir-a/	[kugiira]	'to go for'
/ku-ri-a/	[kurǧa]	'to eat'	/ku-ri-ik-a/	[kuriika]	'to be edible'
/ku-ke-a/	[gukya]	'to dawn'	/ku-ke-ir-a/	[gukeera]	'to dawn for'

In (80), we would expect palatalization to apply in [kugiira], [kuriika], and [gukeera] to yield [kugyiira], [kurgiika], and [gukyeera], respectively. What blocks palatalization in these cases?

Note, first of all, that palatalization does occur in sequences of /i,e/ followed by /i/ in other morphological environments not subject to vowel harmony. For example, in (81), palatalization occurs in the class prefix /iri/ before the /i/-initial stem /ino/:

(81) /ku iri-ino/ [ku rǧiino] 'on the tooth' (Kimenyi p.15)

Thus, it is not the case that any sequence of like vowels blocks

----

26. Prefix /k/ --> [g] before a stem-initial voiced obstruent (Dahl's Law).

palatalization. Rather, it is something related to vowel harmony that blocks palatalization in (80).

Let us compare the derivation of [kunŋweera] 'to drink for', in which both labiovelarization and harmony apply, with that of [gukeera] 'to dawn for', in which only harmony applies. The vowel harmony and labiovelarization in [kunŋweera] is derived in (82), where (82a) is the relevant structure prior to harmony and labiovelarization, and (82b) is the structure after those processes have applied:

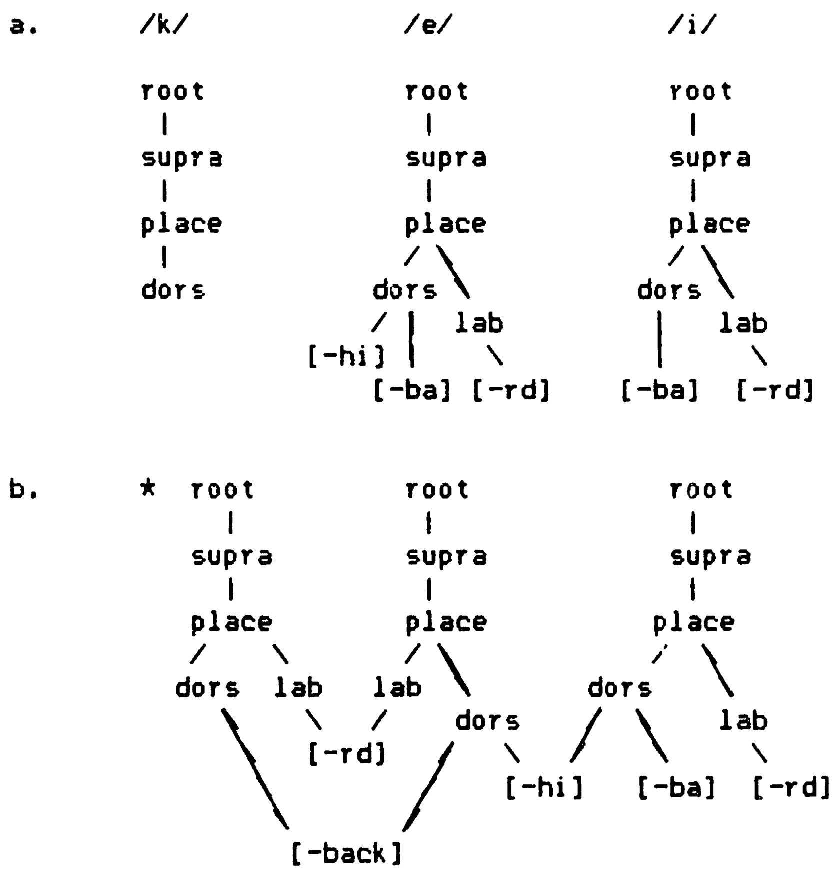
```
(82)    a.      /n/             /u/             /i/

                root            root            root
                 |               |               |
                supra           supra           supra
                 |               |               |
                place           place           place
                 |               / \             / \
                cor           dors  \         dors  \
                              / |   lab        |    lab
                         [-hi]  |     \        |      \
                             [+ba] [+rd]     [-ba]   [-rd]

        b.         root         root            root
                    |            |               |
                   supra        supra           supra
                    |            |               |
                   place        place           place
                    | \          / \            /   \
                   dors lab   lab   \       dors     \
                   /  \   \   /     dors    /  \     lab
                cor    \  [+rd]     /  \   /    \      \
                        \          /  [-hi]  [-ba]   [-rd]
                         \        /
                          [+back]
```

(82) shows that velarization must spread just the feature [back], and not the entire dorsal node. If the dorsal node were spread, then [-high] would be spread onto the consonant along with [+back], which is wrong since the

velar nasal that results must be [+high]. It would be possible to spread the dorsal node in velarization only if [-high] were delinked from the dorsal node either prior to or as a result of velarization. Since there is no other motivation for delinking [high], it is simpler to assume that just the feature [back] spreads, resulting in the structure in (82b).

Consider now the derivation of [gukeera] 'to dawn for'. Based on (82), we would expect (83a) to yield (83b), with a palatalized [ky], but it doesn't. Rather, [-back] fails to spread to the /k/.

(83)



Basically, the structures in (82b) and (83b) are the same; only the values for the features [round] and [back] are different.

Following a suggestion of Donca Steriade (p.c.), I will attribute the application of labiovelarization in (82), and the failure of palatalization in (83) to the fact that height harmony yields a geminate vowel in (83) but does not in (82). Consider again the derivation of vowel harmony in [gukeera] 'to dawn for'.

(84)

```
    a.      /k/             /e/             /i/

            root            root            root
             |               |               |
            supra           supra           supra
             |               |               |
            place           place           place
             |               / \             / \
            dors          dors  \         dors  \
                          / |   lab         |   lab
                     [-hi]  |     \         |     \
                         [-ba] [-rd]    [-ba]  [-rd]

    b.         root         root            root
                |            |               |
               supra        supra           supra
                |            |               |
               place        place          place
               /             / \            /   \
             dors         lab   \       dors     \
                          /    dors     /  \     lab
                     [-rd]    /   \    /    \      \
                             /   [-hi]    [-ba]  [-rd]
                        [-back]
```

After the spreading of [-high] in (84b), the stem and suffix vowels form a linked structure in which all features are identical. Assuming a process akin to Steriade's (1982) Shared Features Convention, which merges all identical features in a linked matrix, we may consider all the features and class nodes in the linked structure in (84b) to merge, yielding (85):

(85)

```
              x           x      x
              |            \    /
            root            root
              |              |
            supra          supra
              |              |
            place          place
               \            / \
                \        lab   \
                 dors    /     dors
                    [-rd]    /    \
                            /    [-hi]
                      [-back]
```

The second and third x-slots in (85) now meet the condition in Kinyarwanda on branching rimes -- since they constitute a geminate vowel, they may be syllabified as a long rime, as in (86):

(86)

```
g u k   e   r a
| | | / \ | |
x x x x x x x
| | | \ / | |
O R O  R  O R
 \|  \ |   \|
  σ    σ    σ
```

Because there is no unsyllabified vowel in (86), there is no palatalization, just as there isn't before the underlying long vowels in (87):

(87)	/ku-siiB-a/	[gusiiBa]	'to be absent'	(K1)
	/ku-seeg-a/	[guseega]	'to beg'	(K1)

That only geminate structures, and not accidental sequences of like vowels, may syllabify as long rimes is shown by the example in (81), /ku iri-ino/ [ku rǧiino] 'on the tooth', in which the accidental sequence of like vowels /..i-i../ does not syllabify as a long vowel, but rather syllabifies like any sequence of vowels -- the first failing to syllabify and causing palatalization, with the vowel length of the second due to compensatory lengthening. Thus, the syllabification in (86) of the sequence of vowels as a long vowel is crucially dependent on the earlier application of vowel harmony which creates a linked structure to which the Shared Features Convention is applicable, ultimately deriving a geminate structure. Sequences of like vowels not in a harmony environment will never syllabify as long rimes because it is only the link provided by harmony that enables the creation of a geminate structure. Syllabification in Kinyarwanda is sensitive to geminate structures, not to accidental geminates -- sequences of vowels which happen to be the same.

To summarize, if vowel harmony results in a sequence of identical vowels, the linked structure formed by vowel harmony is transformed through the Shared Features Convention into a geminate, long vowel, which is syllabifiable as a nucleus in Kinyarwanda. Palatalization then fails because there is no unsyllabified slot. This is the difference between labiovelarization and palatalization in the vowel harmony environment.

With the failure of palatalization in the vowel harmony environment thus explained, we may return to the argument that the labiovelarization in a vowel harmony environment shown in (82) demonstrates that it is the feature [back], and not either the dorsal node or the place node, that is spread in velarization. The only example showing labiovelarization to be spreading [+back] as well as [+round] in the vowel harmony environment is /ku-no-ir-a/ [kuŋweera] 'to drink for'. In the other examples, the consonant is already velar, so there is no way to tell if [+back] has spread. In this example, however, altough the consonant starts out as a coronal, it is also a nasal. Thus, I must show that the velarity of [ŋ] in [kunŋweera] is a result of labiovelarization, and not simply a case of the nasal assimilating in place to the following glide. That this is a case of velarization and not nasal assimilation is shown by the distribution of vowel length in the example. In Kinyarwanda, there are only CV(V) syllables. A sequence of nasal-glide-vowel is not allowed. Rather, in order to attribute the velarity of the nasal to assimilation rather than labiovelarization, we would have to analyze [ŋw] as a prenasalized /w/. However, in Kinyarwanda, all prenasalized segments trigger compensatory lengthening of the preceding vowel. Therefore, because the vowel preceding [nŋw] is short in this example, [nŋw] cannot be a prenasalized segment. Furthermore, the length of the vowel following [nŋw] can only be a result of the /w/ having merged its features onto /n/'s x-slot, i.e. it must be a case of compensatory legnthening triggered by Complex Segment Formation (CSF). These arguments are illustrated in (88). In (88a) is the derivation of a labiovelarized /n/, in (88b) of a prenasalized /w/ (ignoring vowel harmony). The distribution of compensatory lengthening in [kunŋweera] proves that the velarity of the [ŋ] was derived by spreading [+back] from the following vowel, and not by prenasalizing the [w].

```
(88)
a. k u n o i r a        k u n o i r a        k u n o i r a
   | | | | | | |  CSF   | | |/  | | |   CL   | | |/ /| | |
   x x x x x x x  ==>   x x x x x x x  ==>   x x x x x x x   kunŋwiira

b. k u n o i r a        k u n o i r a        k u n o i r a
   | | | | | | |  NAS   | |  \| | | |   CL   | |\ \| | | |
   x x x x x x x  ==>   x x x x x x x  ==>   x x x x x x x  *kuunŋwira
```

To conclude, then, labiovelarization and palatalization in Kinyarwanda must be represented as the spread of [back] and [round] from a vowel onto a consonant. The dorsal and labial articulators that [back] and [round] link to will be minor if they are interpolated as part of the linking of [back] and [round], i.e. if there were no dorsal or labial node already present in the segment affected. If, however, they link to a segment already containing a major dorsal or labial articulator, then they will be part of the major articulation. The major/minor distinction is then crucial in determining the degrees of closure of the various articulators in the resulting segment. Specifically, the major articulator gets whatever degree of closure is phonologically specified for the segment; minor dorsal articulators are strengthened to [-cont]; and minor labial ([+round]) articulators get the universal default for minor articulators -- [-cons].

3.3.4 Fula

The system of consonant gradation in Fula is argued by Anderson (1976c) to contain an instance of two underlying segments being distinguished solely by which of the two articulations in each is primary. The segments in question are a /w/ with primary labial articulation and a /w/ with primary velar articulation. Anderson's analysis translates straightforwardly into the distinction of major and minor articulators proposed above. In this section, I will show how the major/minor distinction applies in Fula. I will argue that because it is more specific than the vaguer primary/secondary distinction, it actually predicts the behavior of the two /w/'s under consonant gradation. Finally, I will show that the Fula data may be alternatively analyzed without making use of a major/minor distinction.

In Fula, there is a morphologically conditioned system of consonant gradation among three classes, referred to as the 'continuant', 'stop', and 'nasal' classes (although not all the consonants in each class are continuants, stops, or nasals, respectively). Correspondences among the classes are given in (89) (from Anderson (1976b)).[27]

(89) a.

Cont	r	w	w	y	y	f	s	h
Stop	d	b	g	g	j	p	č(š)	k
Nasal	nd	mb	ŋg	ŋg	ñj	p	č(š)	k

b.

Cont	b	d	j	g	?b	?d	?y	?	t
Stop	b	d	j	g	?b	?d	?y	?	t
Nasal	mb	nd	ñj	ŋg	?b	?d	?y	?	t

c.

Cont	m	n	ñ	ŋ	mb	nd	ñj	ŋg
Stop	m	n	ñ	ŋ	mb	nd	ñj	ŋg
Nasal	m	n	ñ	ŋ	mb	nd	ñj	ŋg

Anderson (1976b) argues extensively that the "lexical representation of a root or suffix is the form in which it appears in those environments where the continuant grade is called for" (Anderson (1976c:26)). His arguments are that except for the ambiguity of /w/ to be discussed below, given the form of a stem which appears in the continuant grade environment, it is possible to predict the forms of that stem in the other environments, which is not possible taking either of the other two forms as basic.[28] In (89a) are given all the forms which show a [+cont] in the continuant grade. All

----

27. In this section I deal with the system of consonant gradation in the Eastern Fula dialects of Gombe and Adamawa. Western Fula shows a slightly different system.

28. The alternation of/y/ is predictable because it alternates with /g/ before front vowels and with /j/ before back vowels.

of these forms show an alternation between all three grades: continuant, stop, and nasal (except the voiceless obstruents which are immune to nasalization). In (89b) are given given those forms with an oral stop in the continuant grade. These forms show no alternation between continuant and stop grades. This is easily explained if the stop grade is derived by the addition of [-cont] to the initial consonant of the form. Since the forms in (89b) are underlyingly [-cont] (the form they show in the basic, 'continuant' grade), the addition of [-cont] in the stop grade has no effect. Of these forms, the voiced stops show an alternation between stop and nasal grades; the glottalized stops and /t/ are immune to nasalization. Finally, in (89c) are the forms with nasal(ized) stops in their basic form. They show no alternation, because neither the addition of [-cont] in the stop grade nor [+nasal] in the nasal grade has any effect on such segments. Thus, taking the continuant form as basic allows us to derive all the correct forms in the other grades stipulating only that [+nasal] may not link to [+constr] or to [+spread] (or [+stiff]?),[29] except for the alternations of /w/, to which I now turn.

As can be seen in (89a) above, underlying /w/ may alternate with either /b/ or /g/ (before a back vowel -- /w/ alternates only with /b/ before front vowels). There is no clue in the phonetic form of /w/ as to

----

29. Anderson shows that exceptions to the above system of gradation are of the expected types: recent borrowings and derived forms. If either the stop or the nasal grade were taken as basic, however, many fully native and non-derived roots would have to be marked as exceptions to gradation -- all those analyzed as being underlyingly stops or nasals in the above account. An exception not accounted for under any of these hypotheses is /l/, which does not alternate at all.

which stop it will alternate with. /w/ that alternates with /b/ is phonetically identical to /w/ that alternates with /g/. Anderson therefore argues that surface [w] is ambiguous between a velarized labial glide and a labialized velar glide, in my terms, (90a) vs. (90b.):

```
(90)   a.      root               b.      root
                | \                        | \
               sup \                      sup \
                |  [-cons]                 |  [-cons]
               place                      place
                / \                        / \
            labial \                   labial \
              |   dorsal                 |   dorsal
          [+round]  \                [+round]  \
                  [+back]                    [+back]
                  [+high]                    [+high]
```

(90a,b) are identical except for the specification of the major articulator -- in (90a), the velarized labial, the labial articulator is major; in (90b), the labialized velar, the velar articulator is major. This distinction between the two /w/'s allows a straightforward account of the consonant gradation facts. In the stop grade, a specification for [-cont] is attached to the root node, yielding (91a,b):

```
(91)   a.      root               b.      root
                | \                        | \
               sup \                      sup \
                |  [-cont]                 |  [-cont]
               place                      place
                / \                        / \
            labial \                   labial \
              |   dorsal                 |   dorsal
          [+round]  \                [+round]  \
                  [+back]                    [+back]
                  [+high]                    [+high]
```

This [-cont] will apply to the major labial articulator in (91a), yielding [b], and will apply to the major dorsal articulator in (91b), yielding [g] (assuming a pruning of minor articulator nodes in [-cont] segments).

The intimate connection between degree of closure features and what it means to be the major articulation in a segment predicts that processes such as consonant gradation, which operate on closure features, will reveal differences in majorness, whereas place assimilation, which doesn't affect closure features, never will. Basically, since only the major articulation receives the closure features of the segment, any process such as consonant gradation which changes closure features will affect just the major articulation, and not the minor one. This result would not be automatic under the vaguer traditional notion of primary/secondary, since there the connection to degree of closure features is not made explicit.

There exists an alternative to the above analysis which does not make use of the major/minor distinction. This alternative, however, requires the postulation of an abstract segment which never surfaces. Basically, the analysis is to build the history of the consonant gradation system into its synchronic workings. Historically, the consonant gradation system was that in (92a):

(92)

```
a.    Cont    w   Y   y          b.    Cont       w    y
              |   |   |                          / \  / \
      Stop    b   g   j                Stop    b    g    j
              |   |   |                        |    |    |
      Nasal   mb  ŋg  ɲj               Nasal   mb   ŋg   ɲj
```

In (92a), there is a one-to-one relation between the continuant and stop forms. Subsequent to the stage in (92a), however, /Y/ became /w/ before the back vowels /a,o,u/ and became /y/ before the front vowels /i,e/, resulting in the system in (92b), in which /w/ before back vowels may surface as either /b/ or /g/ in the stop grade, and /y/ before front vowels may surface as either /g/ or /j/ in the stop grade. To avoid the problem of determining in (92b) which /w/s become /b/ and which /g/, and which /y/s become /g/ and which /j/, this analysis would simply incorporate the change from (92a) to (92b) as part of the synchronic grammar of Fula. Thus, those surface [w]s and [y]s which alternate with /g/ would be underlyingly velar fricatives, /Y/. /Y/ is not part of the surface inventory of Fula; it will always be either rounded to [w] or palatalized to [y].

Evidence suggesting that this analysis is not quite correct is that a further historical development in Fula resolved the ambiguity of the alternation of [y] with either [g] or [j] in the stop grade, but left the ambiguity of [w] unaffected. Anderson (1976b) notes that

> the indeterminacy of underlying y ... appears only before a following front vowel; and it is in just this environment that original j/ñj alternating with y are systematically replaced by g/ŋg. The result is that, given a y, we can now tell unambiguously what stop it alternates with: if it is followed by a back vowel, it alternates with j/ñj, while if it is followed by a front vowel, it alternates with g/ŋg (p.116).

Thus, it seems that Fula speakers are not treating surface [y] alternating with [g] as an underlying /Y/. Rather, they treat it as underlying /y/, leading to its merger with historical /y/. If we assume that surface [y] alternating with /g/ must be underlying /Y/, then the change of y/j/ñj before front vowels to y/g/ŋg would be a reanalysis of historical /y/ as underlying /Y/, which never occurs on the surface in Fula. It is questionable to assume that a reanalysis would operate to create more of the abstract, non-surfacing segments. If, on the other hand, the merger of [y] derived from *Y and [y] derived from *y is seen as a synchronic elimiation of the abstract non-surfacing segment /Y/, then we would expect

/Y/ to be elimated also as a source of [w].

It is interesting to note that no such merger occurred with respect to the alternations of /w/. Analogous to the development of /y/, we might expect the /w/ forms alternating with /b/ before back vowels to be reanalyzed as alternating with /g/. This does not occur. I propose that the difference between the developments of ambiguous /y/ and /w/ is based in the fact that /w/ is doubly-articulated, and thus contains in its representation both of the articulations with which it alternates, while /y/ contains only a single articulation, and thus is impossible to represent underlyingly as two distinct segments both of which surface unchanged. That is, the major/minor distinction is available for /w/ and allows the situation of /w/ alternating with both /b/ and /g/ to remain; no such distinction is available for /y/, so the ambiguous alternations of /y/ are intolerable and are reanalyzed.

What, then, is the correct analysis for Fula? Both analyses introduce an underlying distinction between [w] which alternates with /b/ and [w] which alternates with /g/, where this underlying distinction is not detectable phonetically in the realization of [w]. The analysis in terms of major and minor articulators introduces the underlying distinction of whether the labial or the dorsal articulator is the major one, i.e. is the one that receives the phonological [-cons] degree of closure of the segment. Universal default rules will always assign the same degree of closure, [-cons], to the minor articulation, so there is no phonetic distinction between /w/ with major labial articulation and /w/ with minor labial articulation. Although this analysis requires the introduction of distinctive major/minor in Fula, it does not require any abstract, non-surfacing segment. Both underlying /w/s contain the featuers they will surface with -- no more and no less. On the other hand, the analysis in terms of underlying /Y/ requires the introduction of an abstract segment, /Y/, which never surfaces in Fula. Given that the major/minor distinction is not used in any other segment in Fula, it might be argued that the former analysis is more costly in its abstractness than the latter. Such an evaluation, however, requires us to compare the abstractness of a major/minor distinction with the abstractness of non-surfacing /Y/. Since these constitute two different types of abstractness, it is difficult to weigh them against each other. I will thus leave the issue unresolved, noting only that the definition of the major/minor distinction as governing the application of phonological degree of closure features, which was proposed for the processes of labiovelarization and palatalization in Nupe, Shona, and Kinyarwanda, and for the clicks and complex segments of !XŨ and Margi, makes exactly the right predictions in the completely unrelated process of consonant gradation in Fula.

3.4 Comparison of Major/Minor Distinction with Alternatives

I have argued in this chapter that the representation of complex segments in Hottentot, Margi, !XŨ, Nupe, Kinyarwanda, and Shona requires a distinction to be made between major articulators, to which phonological degree of closure features apply, and minor articulators, which have no phonological specification for degree of closure and which surface phonetically with non-distinctive degree of closure (either predictable or in free variation). In this section, I show why the distinction of major and minor articulators is preferable to alternative means of distinguishing the complex segments in the above languages.

3.4.1 Separate Degree of Closure for Each Articulator

One means of distinguishing the complex segments discussed above would be to allow the representation of separate degrees of closure for each articulator. As argued above, a serious drawback with using separate degrees of closure for each articulator in complex-segment languages is that it requires the introduction of a basic typological distinction between complex-segment and simple-segment languages as regards the feature hierarchy. In addition to this drawback, however, there are practical problems for this proposal within the analyses of single languages.

For example, although allowing separate degrees of closure for each articulator would correctly distinguish Margi /pt,ps,tw,sw/, it would fail to characterize the fact that although rounded labials may occur in Margi, as in /pw, bw, ?bw, fw, vw, mw/, they may not occur in combination with coronals. This fact would have to be stipulated in an analysis with separate degrees of closure for each articulator, but is an automatic result of an analysis in terms of major and minor articulators. In the latter analysis, /pt,ps,tw,sw/ have major coronal articulators with distinctive degree of closure. The degree of closure of the minor labial articulators in these segments is determined by the phonetic interpretation rules: [-round] --> [-cont]; [+round] --> [-cons]. This prevents rounded labial stops or fricatives from occuring in complex segments with major coronal articulations, since minor labial articulations are always [-cons] if they are [+round]. However, the redundancy rules will not apply to a segment with a major labial articulator, because in these, the degree of closure of the labial articulator is already phonologically specified. Thus, the [+round] labial articulations in /pw, bw, ?bw, fw, vw, mw/ are not required to be [-cons] because, being major articulations, they receive phonological degree of closure specification. In contrast, if /pt,ps,tw,sw/ were distinguished by separate degrees of closure for each articulator, then given that /pw/ is a possible articulation in Margi, we would expect segments such as /tpw, spw/ to also occur, in the absence of any explicit statement preventing them.

Furthermore, there would be no explanation of the behavior of Margi /ps/ as [+cont] phonologically, with respect to prenasalization, under an analysis in which each articulator had its own degree of closure specification. In such an analysis, Margi /ps/ would be represented as in (93), with [-cont] for its labial closure, and hence would be expected to occur prenasalized.

```
(93)            place
                /  \
           labial  coronal
             |        |
           [-cont]  [+cont]
```

Again, it would be possible to add an explicit restriction to the grammar of Margi against prenasalizing [ps], but this restriction would be completely arbitrary. There would be no connection between the impossibility of prenasalizing [ps] and the fact that the fricatives

/f,s,š,.../ may not be prenasalized either.

The biggest problem with allowing separate degrees of closure for each articulator, however, after the impossibility of assimilating place without manner, is that it predicts more complex segment combinations than actually occur in any one language. For example, in !XÕ I argued that there exist both corono-velar clicks, with major dorsal articulators, and velarized coronals, with major coronal articulators. In particular, there exist the four segments in (94).

(94)

```
      tx             ¢x               ǂ              ǂx

   [-cont]     [-cont][+cont]     [-cont]     [-cont][+cont]
      |              \ /             |              \ /
    root            root           root            root
      |               |              |               |
    supra           supra          supra           supra
      |               |              |               |
    place           place          place           place
     / \             / \            / \             / \
   cor   \         cor   \        cor   \         cor   \
        dors            dors           dors            dors
```

However, separate degrees of closure for each articulator predict, rather than the four segments in (94), the nine segments in (95):

(95)	tk	tkx	tx
	¢k	¢kx	¢x
	sk	skx	sx

Allowing degree of closure independently for each articulator predicts the normal case to be for a language that allows corono-velar complex segments to allow all those in (95). If a language imposes additional restrictions on the combinations of degree of closure for each articulator in a complex segment, it will come at extra cost to the grammar. However, I have found no case where a language uses all the oppositions in (95), the so-called normal case under the independent degree of closure analysis.

The impossibility of a system like (95) is explained under my system of major and minor articulators. There are only three possibilities for a corono-velar complex segment: (i) the coronal articulation is major and has distinctive degree of closure while the dorsal is minor and has non-distinctive degree of closure; (ii) the dorsal is major and the coronal minor; and (iii) both the coronal and the dorsal articulators are major, requiring them both to be of the same degree of closure. (i) corresponds to any column of (95), (ii) to any row, and (iii) to the diagonal composed of /tk, ¢kx, sx/. Thus, the maximal contrasts in any system among the nine segments in (95) will be seven. In (96) are given the only possible corono-velar complex segment systems available in language.

(96)

tk	tkx	tx	tk	tkx	tx	tk	tkx	tx
¢k	¢kx			¢kx			¢kx	¢x
sk		sx		skx	sx			sx
tk			tk	tkx		tk		tx
¢k	¢kx	¢x	¢k	¢kx	¢x	¢k	¢kx	¢x
sk		sx		skx	sx			sx
tk			tk	tkx		tk		tx
¢k	¢kx			¢kx			¢kx	¢x
sk	skx	sx	sk	skx	sx	sk	skx	sx

3.4 Comparison of Major/Minor Distinction with Alternatives

The boxes in (96) contain all the possible corono-velar systems under the major/minor articulator analysis. This does not mean, of course, that a language would have to make use of all the oppositions in a particular system. The point is that no language could make use of a combination of oppositions not contained in one of the systems in (96). Furthermore, the inventory of contrasts a language may display is not arbitrary or limited just to a certain number; rather, the contrasts may be only of specific types, forming "series" of "velarized" and "coronalized" complex segments all of which share minor dorsal or coronal articulators, respectively, with non-distinctive degree of closure.

3.4.2 Suction/Pressure or Movement Features

A traditional means of distinguishing certain complex segments has been by features for suction or pressure created in the closed air chamber formed by the two articulations of the complex segment. The most common segments with suction or pressure are implosives and ejectives -- in which the closed glottis either moves down in the throat to create the suction for an implosive, or moves up in the throat to create the pressure for an ejective. Less common are clicks, in which a pre-velar closure is combined with a velar closure, followed by a lowering of the tongue between the two closures to create suction for the pre-velar release. (Segments with velaric pressure are unattested.)

While the above suction and pressure mechanisms are clearly part of the phonetic description of implosives, clicks, and ejectives, I will argue that they are not part of phonological representation. Rather, the suction and pressure may be predicted from other aspects of the segments in question.

3.4.2.1 Ejectives and Implosives

Halle and Stevens (1971) make a three-way distinction among glottalic ([+constr. glottis]) obstruents, corresponding to the three possible combinations of values for the features [stiff vocal cords] and [slack vocal cords]. In their system, ejectives are [+stiff], preglottalized or laryngealized consonants are [+slack], and implosives are [-stiff,-slack], as shown in (97):

(97)

	implosive	preglottalized	ejective
spread glottis	-	-	-
constr. glottis	+	+	+
stiff voc. cords	-	-	+
slack voc. cords	-	+	-

Thus, among obstruents with [+constricted glottis], they distinguish: [b] (imploded) [-stiff,-slack]; [?b] (preglottalized/laryngealized) [+slack]; and [p?] (ejective) [+stiff].

The feature classification in (97) is supported by the behavior of glottalized segments with respect to tone in languages in which the glottal features of a consonant affect the tone of a following vowel. Halle and Stevens explain the relation between glottal features in consonants and tone in vowels as follows:

> Following a suggestion by LaRaw Maran, we propose that in the plain vowels, [+stiff vocal cords] is the articulatory correlate of high pitch, whereas [+slack vocal cords] is the articulatory correlate of low pitch. Neutral pitch for the vowels is produced by the configuration [-slack, -stiff]. We observe that these feature assignments are compatible with the well-known fact that voiceless -- i.e., [+stiff] -- obstruents cause an upwared shift in pitch in the adjacent vowel, whereas voiced -- i.e., [+slack] -- obstruents cause a downward shift in pitch.

One example where tone facts support the feature classification in (97) is in the history of Hottentot, where the ejective consonants /t?,k?/ pattern with voiceless [+stiff v.c.] segments in failing to lower the tone of a following vowel, unlike [+slack v.c.] voiced consonants or [-stiff v.c., -slack v.c.] sonorants which lower the tone of a following vowel. Greenberg, also, notes that

> There is evidence from areas as distant as New Guinea, Southeast Asia, and distinct areas of Africa that consonants affect the pitch of adjacent vowels, particularly those which immediately follow. The most important principle is that plain voiced or breathy voiced consonants, particularly obstruents, lower the pitch of the entire vowel segment or that portion which is immediately adjacent so that, for example, a following high tone becomes a rising tone.
>
> On the other hand, a voiceless plain or aspirated segment has no such lowering effect. An ejective likewise fails to lower pitch. A voiced injective stop here has an effect identical with or more similar to that of voiceless and ejective consonants than to ordinary breathy or voiced consonants, i.e. it does not lower tone. All of these non-lowering sound types may even on occasion raise pitch (p.132).

Thus, in these languages only [+slack v.c.] segments lower the pitch of following vowels. The ejectives and implosives, both of which are [-slack v.c.], thus fail to lower pitch.

Further confirmation of the classification in (97) comes from an assimilation process in Tera, discussed in Newman (1970:158-9). In Tera, there is what Newman calls a "linker" consonant which is inserted in certain morphological environments. This consonant, a /t/, assimilates to the preceding segment as follows:

(98)	t	-->	r /	V	___
			d /	[C, +slack v.c.]	___
			nd /	[C, +nasal]	___
			t /	elsewhere	___

The implosives in Tera (b′, by′, d′, j′, g′) pattern not with the voiced consonants but with the voiceless, non-nasal ones. Examples, where /t/ is inserted between a noun and a plural marker, determiner, or modifier, are given in (99a). Further examples in other morphological environments are given in (99b).

(99)

a.	goma - t - ku	gomarku	′markets′
	sabi - t - bana	sabirbana	′my stick′
	tlug - t - ku	tlugdəku	′knives′
	dlem - t - ku	dlemndəku	′ears′
	shok - t - ku	shoktəku	′squirrels′
	shok - t - a	shokta	′the squirrel′
	xad′ - t - ku	xadtəku (-> xa:təku)	′illnesses′
	sed′ - t - ku	sedtəku (-> se:təku -> setəku)	′snakes′
b.	wa jam - t nda	wa jamnde nda	′he asked him′
	wa dlab′- t na	wa dlabte na	′he beat me′
	wa dud′ - t na	wa dudte na (-> wa du:te na)	′he tugged me′

Since Halle and Stevens represent implosives as [-stiff,-slack], it follows that they will not pattern with the voiced consonants in (99), which are [+slack].

Further evidence against distinguishing ejectives and implosives by independent features of suction or pressure is that ejectives and implosives never contrast within a language without also contrasting for some other feature. That is, a language never contains two segments which differ solely by whether there is glottal pressure or suction or not. For example, Greenberg (1970) states that "a few Mayan languages have a contrast between an ejective p′ and an implosive in the same position. When this occurs the implosive is generally voiced in all its realizations so that a contrast based solely on injection versus ejection without accompanying voicing contrasts does not usually exist" (p.126). Greenberg concludes by "tentatively [accepting] the thesis that the contrast between injection and ejection need not be accepted as autonomous for general phonetic theory. The implosive is normally voiced, but voiceless occurs typically in word final where ordinary 'voiced' obstruents are subject to devoicing. It seems likely, therefore, that the constant feature here is also laxness. Hence one might have a common feature glottalic that is concomitantly injective with the lax feature and ejective with the tense feature" (p.126-7). Greenberg's use of tense and lax in this context corresponds to Halle and Steven's use of [stiff v.c.] and [slack v.c.].

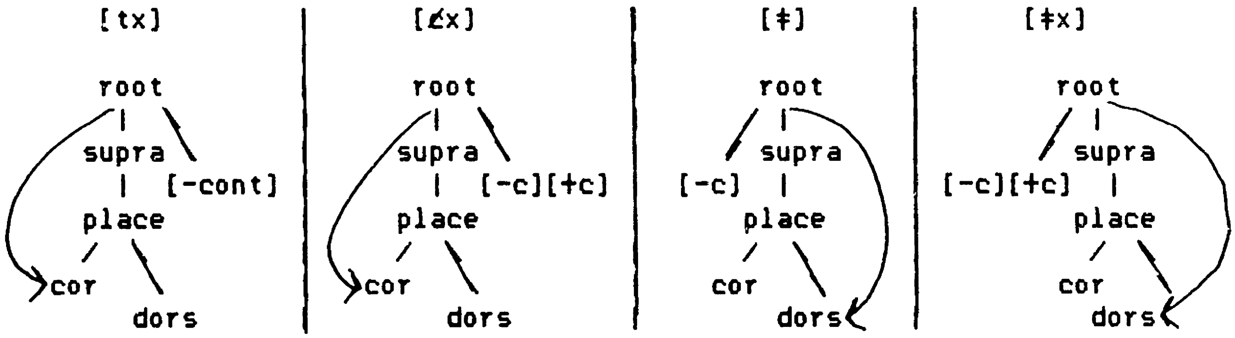
Thus, Halle and Stevens show that it is not necessary to appeal to pressure or suction features (or glottal movement features) in order to distinguish implosives and ejectives. Rather, the independently necessary features [stiff v.c.] and [slack v.c.] make the necessary distinctions. Furthermore, characterizing the distinctions in terms of [slack v.c.] and [stiff v.c.] explains the behavior of these consonants in languages where glottal features affect tone. If they were merely [+constr. glottis] with suction or pressure features, their patterning with respect to tone would be unaccounted for. Finally, distinguish ejectives and implosives by the features [stiff v.c.] and [slack v.c.] accounts for the fact that no language will contrast implosives and ejectives at the same point of articulation and with identical states of the vocal cords, i.e. identical voicing. Based on these arguments, although Halle and Stevens choose to "leave open for the present the question whether the raising of the glottis in the ejective and the lowering of the glottis in the implosive should be attributed to separate features in the universal framework" (p.211), I conclude that separate features for raising or lowering the glottis would be not only superfluous, but would fail to make the right predictions concerning the behavior and patterning of glottalic consonants. Such features, therefore, do not exist.

3.4.2.2 Clicks

The remaining area for which suction features have been proposed is for the velaric suction in clicks. As with the suction and pressure in glottalic consonants, however, the suction in a click is never its sole distinguishing characteristic. Rather, the distinction of major and minor articulators, which is independently necessary for complex segments not involving suction and thus not distinguishable by suction, makes all the necessary distinctions for the clicks.

Consider the corono-velar complex segments in !Xũ, discussed above. Recall that in !Xũ, there is a contrast among the four corono-velars in (100), represented in terms of major and minor articulators:

(100)



To represent the segments in (100) instead by suction features would not accomplish all that the representation in (100) does. First, we could assume that in a segment with suction, the anterior closure must be [-cont] redundantly and any phonological degree of closure features apply to the velar closure. This will correctly derive that in the third and fourth segments in (100), in which there is phonetic suction, the degree of closure features apply to the velar articulation. However, the first and second segments in (100) will simply lack suction features, and thus the problem will remain of representing the fact that the phonological degree of closure in those segments applies to the coronal articulation. We could save the solution for !Xõ by stipulating that in non-suction segments, the more anterior closure receives the phonological degree of closure features. However, this would have to be a language-specific stipulation, for it is not always the case that non-click complex segments choose the more anterior articulation as major. For example, in Margi [ps], the coronal articulation, which is more posterior than the labial articulation, is nevertheless the major articulation. Similarly, in Kinyarwanda [skw], the coronal articulation, which is neither the most anterior nor the most posterior, is the major articulation. Finally, Nupe [py] and [pky] contrast solely in which articulation is the major one -- there is no suction in [pky] by which to distinguish it.

In some Shona dialects, adding a dorsal articulation to a bilabial nasal, i.e. velarizing it, may result in a nasal click. Compare the forms for 'child' and 'to drink' in the three Eastern Shona dialects in (101).

(101)

Ndau	m͡ŋana ~ mwana (one speaker)		'child'	(161)
Tonga	m͡ŋana		'child'	(161)
	k'um͡ŋa		'to drink'	(161)
Teve	mω̃ana		'child'	(161)
	kumwa		'to drink'	(161)

In Ndau and Tonga, clicks result from the simple combination of labial and velar articulations. This fact argues against the representation of clicks as having phonological suction features. In Ndau and Tonga, there is no suction feature in the environment which could be posited to trigger the creation of the click. In a theory in which clicks have no suction features, but rather are represented as identical to egressive complex segments, the derivation of clicks in the environments in Ndau and Tonga is perfectly natural.

Furthermore, as with the implosives and ejectives discussed above, a language will never contrast two segments solely by whether there is velar suction or not. For example, the click and non-click segments in !Xũ, shown in (101), also contrast in degree of closure of the dorsal articulation. While it would be possible to derive the different degrees of closure under a suction analysis, the major/minor analysis <u>predicts</u> a difference in the behavior of degree of closure between the clicks and non-clicks, since the crucial distinction between them is in the choice of major articulator, which is merely the articulator to which the degree of closure features apply.

Thus, it is clear that a velaric suction feature would be of much more limited use than the major/minor articulator distinction. Since the major/minor distinction is needed in any case for complex segments in which there is no suction, I conclude that it is preferable to distinguish the clicks of !XŨ in terms of major and minor articulators, rather than in terms of suction features.

3.5 Further Applications of Major/Minor

I have shown in this chapter that a distinction in terms of major and minor articulations, so that only major articulations receive the phonological degree of closure features, allows us to capture straightforwardly the derivation and behavior of complex segments, as well as to constrain the possible complex segment inventories in language. Is assignment of degree of closure features the only process majorness is relevant for? I have already shown that major and minor are irrelevant for place assimilation. However, there are a few examples which show that languages make use of the major/minor distinction in other ways.

3.5.1 Ngbaka

In Ngbaka, the distinction between major and minor articulators plays a role in word-internal cooccurrence restrictions. The consonant system of

Ngbaka is that in (102), from Thomas (1963).[30]

(102)

p	f	t	s	k	kp	
b	v	d	z	g	gb	
ʼb						
mb		nd	nz	ŋg	ŋmgb	
m		n		ñ		
		l		y	w	
						?
						h

The consonants represented by more than one letter in (102) are single segments. Thomas states:

> La durée de [mb] est sensiblement égale à celle d'un [b] ou d'un [m]. Pour le sujet parlant, c'est un phonème unique indécomposable, et si l'on prononce le groupe de consonnes [m], suivi de [b], l'informateur proteste. Ceci est valable pour tous les phonèmes notés ci-dessus au moyen de plusieurs symboles successifs (p.28).

Furthermore, the syllable structure of Ngbaka allows only CV syllables,[31] as seen by the syllabification of French loans shown in (103):

(103)

piyElE	'prière'	(45)
mbalase	'embrasser'	(131)
nzidOlO	'citron'	(40)
kElEyõ	'crayon'	(45)
kElEdE	'crédit'	(131)
kalamele	'réclamer'	(131)
?afElEmE	'infirmier'	(37)

----

30. Thanks to Donca Steriade for pointing out this example. Thomas actually writes the prenasalized velar and labiovelar as "ng" and "ngb", not as "ŋg" and "nmgb". However, she describes them respectively as "mi-nasale dorsale" and "mi-nasale labio-dorsale", so it is clear that the orthographic "n" does not imply phonetic [n], but rather stands for a nasal articulation of the same place of articulation as the following stop, as I have represented them in (102).

31. Thomas writes sequences of vowels for short diphthongs and vowels bearing contour tones, but clearly states that "il s'agit d'une syllabe unique et ... cette modulation ne s'accompagne pas d'une longueur" (p.20).

zalẽdẽ	'jardin'	(40)
kOlOdiõ	'cordonnier'	(40)
lizi	'riche'	(41)

Also, prenasalized consonants and labiovelars reduplicate as single segments. Consider the data in (104) and (105) (from Thomas pp.124-135).

(104)	siti	'bad'	sisiti	'wickedness, ugliness'
	ndu	'short'	ndundu	'shortness'
	mbẽ	'brown, dark'	mbẽmbẽ	'brownness, darkness'

(105)	<u>Verb</u>	<u>Noun</u>	
a.	ha	haha	'take'
	molo	momolo	'kill'
	kOlO	kOkOlO	'cut'
	sEkE	sEsEkE	'clean'
	sakpa	sasakpa	'loosen, set free'
	lOndOlO	lOlOndOlO	'plaster'
	sEŋgElE	sEsEŋgElE	'string (beads)'
b.	sia	sisia	'tear'
	sua	susua	'hammer'
	ziE	ziziE	'vomit'
	kio	kikio	'pierce'
c.	kpO	kpOkpO	'glue, weld, fasten'
	kpele	kpekpele	'deliver'
	kpeseke	kpekpeseke	'roar'
	gbo	gbogbo	'shout'
	gbO	gbOgbO	'hit'
	gba	gbagba	'cover'
	gbOma	gbOgbOma	'threaten'
d.	mbi	mbimbi	'gather around'
	mbalase	mbambalase	'embrace (a child)'
	nzia	nzinzia	'finish, achieve'
	nzoŋga	nzonzoŋga	'take an oath'
	nzObOkO	nzOnzObOkO	'embrace'
	ŋgua	ŋguŋgua	'smoke'
	ŋgima	ŋgiŋgima	'thunder'

The forms in (105a) show reduplication of the first consonant and vowel in forms with simple initial consonants and monophthongal rimes. The diphthongs in (105b) are monosyllabic (Thomas p.128,130). Thus, the forms in (105b) show that it is not the entire first syllable that is reduplicated, but rather only the first consonant and vowel. Finally, the forms in (105c) show labiovelars reduplicating as single segments, and the forms in (105d) show the same for prenasalized consonants.

Thus, timing, syllabification, and reduplication show that /kp, gb, mb, nd, nz, ŋg, ŋmgb/ are all single segments.

Given that the labiovelars /kp,gb,ŋmgb/ are single segments, they must be represented with two articulators, labial and dorsal, under the place node, of which one or both may be the major one. I shall show below, based on cooccurrence restrictions, that in /kp,gb,ŋmgb/, the labial articulation is the major one, and the dorsal the minor one. I.e., they are represented as in (106):

(106)

```
/kp/     root
        / | \
       /  supra\
laryng     \     [-cont]
  |         \
[+stiff]   place
           /  \
      labial   \
              dorsal
```

```
/gb/     root
        / | \
       /  supra\
laryng     \     [-cont]
  |         \
[+slack]   place
           /  \
      labial   \
              dorsal
```

```
/ŋmgb/         root
                |  \
              supra  \
              /    \  [-cont]
        soft-pal    \
          / \      place
   [+nas] [-nas]   /  \
                  /   labial
             dorsal
```

In Ngbaka, the following pairs of consonants may not occur within the same (non-compound) word (in either order):[32]

----

32. Many apparent exceptions to this generalization involve loan words or compounds. For example, /moŋmgba/ 'slander' (45) and /mogba/ 'entrance to village' (45) both contain the morpheme /mo/ 'mouth' (see p.38). Thus, they are compounds, and as such do not violate the generalization that labials and labiovelars do not cooccur. Two forms that aren't obviously either compounds or loans are /ŋmgbapO/ 'true' (47) and /gizaka/ 'roll' (41), although further investigation may reveal them to be so. Note that sequences of identical consonants are allowed, as in /babã/ 'companion' (p.24), /tita/ 'grandparent' (p.30), and /zozi/ 'judge' (p.41).

(107)

a. voiceless--voiced	b. voiced--prenasalized	c. prenasalized--nasal
p - b	b - mb	mb - m
t - d	d - nd	nd - n
s - z	z - nz	nz - n
k - g	g - ŋg	ŋg - ŋ
kp - gb	gb - ŋmgb	ŋmgb - m

d. labial-labiovelar

p - kp	b - kp	mb - kp	m - kp
p - gb	b - gb	mb - gb	m - gb
p - ŋmgb	b - ŋmgb	mb - ŋmgb	m - ŋmgb

There is, however, no restriction on combinations of velars and labiovelars within a word, as shown by the forms in (108):

(108)	w0-gb0k0	'weak'	(39)
	z0-gb0k0	'swollen'	(39)
	gbanzaka	'without leaves'	(47)
	gboko	'incandescent'	(34)
	kukpe-la	'eyelid'	(42)
	kakpe	'slave'	(43)
	kpaŋga	'large mat'	(44)
	gb0ŋg0	'a small basket'	(58)
	ŋmgboko	'he-goat'	(34)
	ŋmgbaka	'Ngbaka'	

Thus, there is a basic difference in the relationship between labiovelars and labials, versus that between labiovelars and velars. I account for this difference, following a suggestion by Donca Steriade (p.c.), by representing the labiovelars as having major labial articulation, as shown in (106). Thus, they share with simple labials the property of having major labial articulation, and share no major articulator with the simple velars. The cooccurrence restrictions in Ngbaka, shown in (107), may thus be characterized in terms of major articualations, as follows. Within a word, no two consonants may occur which share the same major articulator and degree of closure, but which differ in glottal articulation (107a), nasal articulation (107b,c), or minor articulation (107d). These restrictions on cooccurrences within a word (in either order) are shown formally in (109).

(109)

```
*          root                            root
          / | \                           / | \
  laryng.   |  [a cont]           laryng.   |  [a cont]
     |    supra                      |    supra
[a stiff]   |                  [-a stiff]   |
[b slack] place                [-b slack] place
            |                               |
        a articulator                   a articulator
---------------------------------------------------------------
*          root                            root
          /   \                           /   \
      supra  [a cont]                 supra  [a cont]
      /     \                         /     \
  soft-pal   \                    soft-pal   \
   /   \      place                  |        place
[+nas][-nas]    |                 [-nasal]      |
             a articulator                   a articulator
---------------------------------------------------------------
*          root                            root
          /   \                           /   \
      supra  [a cont]                 supra  [a cont]
      /     \                         /     \
  soft-pal   \                    soft-pal   \
   /   \      place                  |        place
[+nas][-nas]    |                 [+nasal]      |
             a articulator                   a articulator
---------------------------------------------------------------
*          root                            root
          /   \                           /   \
      supra  [a cont]                 supra  [a cont]
        |                               |
      place                           place
      /   \                             |
  a artic. \                        a articulator
         b articulator
```

Note, incidentally, that the pairs b-kp, p-gb, mb-gb, b-nmgb, and m-nmgb violate both the restriction in (107d) and one of the restrictions in (107a,b,c).

Pairs not agreeing in degree of closure are not subject to the restrictions noted above. For example, although the pairs "nd - d" and "nz - z" are disallowed, the pairs "nz - d", "nd - l", "nz - l" are allowed, as shown in (110).

(110)	nzid0l0	'citron' (loan)	(40)
	ndulu	'to deceive'	(29)
	nzulu	'flour'	(32)

Similarly, although the pairs "t - d" and "s - z' are disallowed, the pairs "s - d", "t - l", and "s - l", whose members differ in degree of closure, are allowed.

(111)	sakade	'thus'	(40)
	tolo	'strike'	(29)
	sulu	'to rain very hard'	(31)

This sensitivity of the cooccurrence restrictions to degree of closure is further support for their being sensitive only to major articulators -- for only major articulators are speci.ied for degree of closure. Given that the cooccurrence restrictions are sensitive to degree of degree of closure, it would be impossible for them to apply to minor articulations.

3.5.2 Margi

I argue above that in Margi labiocoronals, the major articulation is the coronal one, and the labial articulation is minor. An extension of this distinction between the labial and the coronal articulations is that in fast speech, when the labiocoronals are simplified, it is the labial articulation that is deleted. Hoffman states: "some speakers of Margi have a tendency to reduce initial compound consonants to simple consonants, especially in a more colloquial type of speech" (p.43).

(112)

/bdəli/	[dəli]	'Dille'
/ptəl/	[təl]	'chief'
/čipčə/	[pčipčə]	'clean'
/bɟir/	[ɟir]	'a (large) cricket'
/bɟabɟagə/	[ɟabɟagə]	'a small bat'

Also, historically related languages have dropped the labial portion (Hoffman p.6):

(113)

South Margi	Margi	
təl	ptəl	'chief'
sar	psar	'grass'
dau	bdə	'to chew'
ɮau	bɮə	'to forge'
zər	bzər	'son'
təka	əmnptəka	'hen'
tətau	mnptəmnptə	'dead'
ɨagu	mnpɨagə	'master'
či	əmnpči	'skin'
čir	mnpčir	'nose'

While nothing in the distinction between major and minor articulators predicts the minor articulator to be more likely to be deleted, it makes sense that in situations where a complex segment is being simplified by the deletion of an articulator, it is the articulator which is less fully integrated into the structure of the segment -- i.e. the minor articulator -- that is deleted.

3.5.3 Palatalization and Distribution of Velars in Hottentot

In Hottentot, the degrees of closure of both the coronal and the velar articulations in clicks are predictable. Thus, degree of closure facts do not determine which articulator is the major one. However, there is an interesting set of data relating to palatalization in Hottentot which, if resolved in terms of a major/minor distinction in the clicks, might bear on the issue of whether languages make use of the major/minor distinction in areas not directly related to degree of closure.

In both the Nama and the Korana dialects of Hottentot, velar consonants are restricted in distribution and subject to palatalization. This is a potentially interesting area to investigate with respect to clicks in these languages, since clicks contain velar closures. First, the simple velar consonants: In Nama, underlying /k/ becomes [č] before [e]. Otherwise, underlying /k/ (surface [k]) occurs only before the vowels /a,o,u,^/ and their nasal cognates (if any). That is, underlying /k/ simply fails to occur before /i/. In Korana, underlying /k/ does occur before /i/, but it is palatalized and realized phonetically [č] before /i/ as well as before /e/. Comparison of Nama and Korana reveals that Korana roots containing underlying /ki/ (surface [či]) correspond to Nama roots with underlying /ti/. This is illustrated by the cognate pair in (114) (Beach p.213):

(114)	Korana	/ki-si/	[čisi]	'ten'
	Nama	/ti-si/	[tisi]	'ten'

In both Nama and Korana, /kx,x/ do not occur before /i,e/; they occur only before /u,o,a,^/ and their nasal cognates (if any). Based on the development of Hottentot /ki/ to /ti/ in Nama, we might hypothesize that /kx,x/ before /i,e/ became /ts,s/ historically in both dialects. This would account for the lack of /kx,x/ before /i,e/.

I now consider the clicks in Hottentot, which, since they contain velar plosive and affricative effluxes, might be expected to be affected by these processes affecting the simple velar consonants. However, this is not the case. First, the distribution of the clicks is not restricted with respect to the following vowel. Beach states (p.88) that while clicks are restricted to initial position (except in reduplication), "they occur before <u>all</u> the vowels and vowel combinations" except "the rare neutral vowel [ə]." Examples of clicks occurring before /i,e/ are given in (115) (all from Nama, which, recall, has the more restricted distribution of /k,kx/):

(115)

ǂxi	'be glad'	(90)	!xe	'spy'	(91)
!xi	'to spy'	(137)	|?i-pa	'him'	(103)
ǂxi-p	'peace'	(133)	ǁxi	'pinch'	(133)
|i-p	'smell of fat'	(137)	ǂi	'be blind'	(137)
ŋǂi	'cheeky'	(135)	|i-nap	'a fly'	(193)
|?i	'to'	(103)	ŋ|i-si	'perhaps'	(104)
|xis	'came'	(105)	ǂai-|?i	'call-on'	(103)

Strikingly, while Nama /kx/ never occurs before /i,e/, and Nama /k/ never occurs before /i/ and is palatalized to [č] before /e/, clicks in Nama containing /k/ and /kx/ as efflux occur freely before /i,e/, and there is no mention of palatalization. That there are so many examples of this is all the more striking in light of the fact that such examples would not be expected to be very numerous, since the restrictions on vowels in the roots tend to exclude /i/ in the first syllable.[33]

----

33. Many /i/'s in Nama are derived from historical /ai/ > /ei/ > /e/, according to Beach (p.193). While this fact could be used to explain clicks containing velar constrictions occurring before /i/, where they shouldn't occur, such an explanation would predict that also the simple consonants /k,kx,x/ should sometimes occur before /i/ (where that /i/ derives from /ai/). Since there are no cases of /k,kx,x/ occurring before /i/, I conclude that the historical source of the /i/'s in (115) is

Thus, the Hottentot clicks do not behave as sequences of coronal followed by velar.

On the other hand, the Hottentot clicks cannot be regarded as phonological sequences in which the velar comes first, because the pronunciation of the click requires that the velar release slightly follow the coronal release. Rather, the clicks must be represented as having simultaneous coronal and dorsal articulations.}

Why are the velar articulations in the clicks immune to palatalization? We might hypothesize that only major dorsal articulations are palatalized in Hottentot, and that the dorsal articulations in clicks are immune to palatalization because they are minor. Hottentot would, under this view, be hypothesized to have extended the major/minor distinction beyond just dealing with degree of closure. However, given that the major/minor distinction is irrelevant for place assimilation, there is no reason for the minorness of an articulation to prevent it from undergoing palatalization.

There are some possible alternative solutions to the failure of clicks to palatalize which don't rely on the major/minor distinction. For example, we might speculate that it is the fact that the dorsal articulation in a click is combined with a coronal one that prevents it from palatalizing to a coronal. For if the dorsal articulation became a coronal one, then there would no longer be a click. It would be impossible

----

irrelevant.

to make two different coronal articulations simultaneously, which would be necessary to produce the suction of a click. By this explanation, the failure of palatalization in Hottentot clicks would be attributed to a vague sort of structure preservation, by which the "clickness" of the click, i.e. its velar articulation, is preserved. This is, of course, only suggestive of what a possible solution to this problem might be.

Alternatively, the non-palatalization of the clicks could be attributed to historical factors, i.e. either (i) the clicks were borrowed into Hottentot (from Bushman) after palatalization had become non-productive, or (ii) the palatalization process itself was borrowed along with the non-click vocabulary, and so didn't apply to the native clicks. Alternative (ii) would liken non-palatalization of clicks in Hottentot to the non-participation in English of native velars in velar softening. Evidence for (ii) is that almost all roots in Hottentot begin with cicks, suggesting an earlier stage of the language in which all roots began with clicks. Evidence for (i), on the other hand, is that the Khoisan click inventories are far more extensive than that of Hottentot (see the !XŨ clicks above), and that click inventories, being marked, tend to be reduced when borrowed into a language (as seen in the restricted inventory of clicks in Zulu and other Bantu languages which have borrowed their clicks from Hottentot and Khoisan). In either case, the developments would have had to occur farther back in time than the history of Hottentot has been reconstructed. So, while these historical scenarios remain possible explanations of the failure of Hottentot clicks to palatalize, they cannot be proved either way.

3.6 Summary

In this chapter, I have proposed a representation for degree of closure features (at the root node) and a mechanism for applying degree of closure features to the correct articulator. This mechanism is the selection of a major articulator or articulators, where the major articulator receives the phonological degree of closure features.

Minor articulations are not phonologically specified for degree of closure. The degree of closure of a minor articulation is predictable, for instance it may be derived by fortition (Margi [ps], Kinyarwanda [skw]) or by taking on the degree of closure of the major articulation (Margi [fs] ~ /ps/ (Hoffman p.28); Shona [sxw]). Often, there is free variation concerning the degree of closure of the minor articulation, as was seen for many Shona dialects. Finally, in most of the languages of the world, minor articulations are required to be [-consonantal] phonetically (as in Nupe). Thus, I hypothesize that the assignment of [-consonantal] at phonetic interpretation is the universal default.

Chapter 4

PHONOLOGICAL FEATURES

In light of the structural changes argued for in the previous chapters, a redefinition of the set of phonological features is required. First of all, a new distinction has been introduced between traditional features, the terminal nodes of the feature hierarchy in (1), and class features, the non-terminal nodes of the hierarchy in (1).

(1)

```
                     root
                    /  \ \ \___cont
                   /    \ \ cons
                  /      \
          laryngeal       supralaryngeal
          / /  |   |         /          \
  constr / /   |   |    soft-pal        place
    spread     |   |       |            / |  \
         stiff     |     nasal     labial |   \
                 slack                /   |    dorsal
                                  round   |    | \  \
                                      coronal  |  \  back
                                       / \    high low
                                     ant dist
```

4.1 Class Features

Class features differ from terminal features in that while the latter may be specified either plus or minus, the former are only either present or absent. There is no minus value for a class feature like labial.

Rather, the presence of a class feature has a particular meaning. Five of the class features refer to independent articulators in the vocal tract. These are: laryngeal, soft palate, labial, coronal, and dorsal. The specification of one of these class features in a segment means that the articulator the class feature represents is present as an active articulator in the segment. It says nothing about degree of closure or what to do with that articulator -- just that it is activated. Therefore, these class features may be defined as in (2):

(2)

LARYNGEAL - Involving the glottis as an active articulator (distinctively).

SOFT PALATE - Involving the soft palate as an active articulator (distinctively).

LABIAL - Involving the lips as an active articulator (distinctively).

CORONAL - Involving the tongue front as an active articulator (distinctively)

DORSAL - Involving the tongue body as an active articulator (distinctively).

The other class features do not refer to specific articulators. In fact, they do not seem to have any anatomic motivation at all. Rather, the supralaryngeal and place constituents correspond to definable acoustic properties of the features they contain. The supralaryngeal features are distinguished acoustically from the laryngeal features in that laryngeal features cause no distortions of formant structures, whereas supralaryngeal features do distort formants. Thus, we may define supralaryngeal as in (3):

(3) SUPRALARYNGEAL Distorting formant structures.

Similarly, the grouping of labial, coronal, and dorsal features under a place constituent, excluding the soft palate features, may be attributed to the fact that features within the place node exert much stronger, and different, influences on formant structure than does nasality. I thus define the place node as in (4):

(4) PLACE — Affecting formant structures in a manner resulting from changes in the shape of the resonator.

Finally, there is a class node that is not motivated by either anatomy or acoustics. This is the root node. It simply corresponds to the phonological entity, the phoneme. Thus, the root node is defined as in (5):

(5) ROOT — Phoneme.

Specification of just a root node is the representation of a maximally underspecified segment. That is, there is a distinction between a maximally underspecified segment, as in (6a), and an empty x-slot, as in (6b).

```
(6)   a.    x                  b.     x
            |
          root
```

Since an underspecified segment nevertheless contains a root node, it will associate correctly in root-and-pattern morphology. The empty root node will link to the skeleton like any other phoneme. If, on the other hand, a maximally underspecified segement had no root node, it could not associate and would result in (7b) rather than the correct (7a).

```
(7)   a.    [ ]         [ ]        b. *  [ ]        [ ]
             |           |                |          |
           root  root  root             root       root
             |     |     |                |        /
             x     x     x                x     x     x
```

Since the class nodes just discussed cannot be specified as minus, it is impossible to spread a minus value for a class node. It is, however, still possible to refer to the property of not involving a particular class node, just as it is possible to refer to the absence of other structures in phonology, for example reference to unsyllabified slots as lacking syllable structure. Thus, for example, we may refer to a lack of coronal articulation by referring to absence of a coronal node. What is not possible is to spread, or assimilate, absence of coronal articulation. Absence of coronal articulation could be spread only by spreading a place node not dominating coronal, and then delinking the prior place node. But this entails spreading whatever other articulators and place features are on the triggering segment's place node. That is, it is impossible to spread the negative property of lacking a certain articulator without also spreading the positive property of having whatever articulator(s) there are on that place node. This is illustrated in (8):

```
(8)      supra    supra
           |        |
         place    place
           |        |
        coronal   labial
```

In (8), in order to assimilate lack of coronal articulation from the second segment onto the first, we must spread the place node, and hence also assimilate the labial articulation.

4.2 Terminal Features

The principle change in the terminal features brought about by the proposals in Chapters 1, 2, and 3 is the following: each terminal feature occurs under one and only one class node. Thus, it is impossible for, e.g., [distributed], as a place of articulation feature, to apply to both labials and coronals. Similarly, [anterior] may apply only to coronals, and not to labials or dorsals. Furthermore, a terminal feature that occurs under an articulator node in the hierarchy may not be specified in a segment unless the corresponding articulator node is also specified. Even the minus values of these terminal features now imply involvement of a particular articulator. Recall, for example, the demonstrations in Chapter 2 that [-round] implies labial, and that [-back] implies dorsal. These constitute significant differences between the definitions of the terminal features in the standard theory, i.e. SPE, and the definitions argued for here. The definitions of the terminal features under the articulators in (3) are as follows:

(9)
a. <u>Under the LABIAL node (implies LABIAL).</u>

[+round]	Rounded lips.
[-round]	Spread lips.

b. <u>Under the CORONAL node (implies CORONAL).</u>

[+anterior]	Constriction formed by the tongue front in front of the palato-alveolar region.

[-anterior] Constriction formed by the tongue front behind the palato-alveolar region.

[+distributed] Constriction formed by the tongue front that extends for a considerable distance along the direction of air flow.

[-distributed] Constriction formed by the tongue front that extends only for a short distance along the direction of air flow (SPE p.312).

Note, importantly, that [anterior] is defined as involving the tongue front. Thus, labials are not [+anterior], nor are velars [-anterior]. This differs from the definition in SPE, by which [anterior] referred solely to the point of constriction in the vocal tract, regardless of which articulator formed that constriction. Similarly, [distributed] is defined as involving the tongue front, so that labials and labiodentals are no longer distinguished by [distributed], but must be distinguished solely by [continuant]. See Steriade (1986) for arguments that [anterior] and [distributed] apply only to coronal articulations.

c. Under the DORSAL node (implies DORSAL).

[+high] Raised tongue body.

[-high] Involving the tongue body, distinctively not raised.

[+low] Lowered tongue body.

[-low] Involving the tongue body, distinctively not lowered.

[+back] Retracted tongue body.

[-back] Fronted tongue body.

d. Under the LARYNGEAL node (implies LARYNGEAL).

[+spread gl] Spread glottis.

[-spread gl] Involving the glottis, distinctively not spread.

[+constr gl] Constricted glottis.

[-constr gl] Involving the glottis, distinctively not constricted.

[+stiff v.c.]	Stiff vocal cords.
[-stiff v.c.]	Vocal cords distinctively not stiff (e.g. mid tone).
[+slack v.c.]	Slack vocal cords.
[-slack v.c.]	Vocal cords distinctively not slack (e.g. mid tone).

e. Under the SOFT PALATE node (implies SOFT PALATE).

[+nasal]	Lowered soft palate.
[-nasal]	Raised soft palate.

The degree of closure features [continuant] and [consonantal] differ from the features above in that they are not tied to any particular articulator. Rather, they specify the degree to which other articulators are activated. [Continuant] and [consonantal] are linked directly to the root node. Not being specified under an articulator, they may apply to any articulator. Which articulator they apply to in any particular segment is determined by the selection of a major articulator, as discussed in Chapter 3. [Continuant] and [consonantal] are defined in (10). They imply only the root node -- i.e. that there is a phoneme.

(10)

[+consonantal]	Involving a closure to the degree [+consonantal] by the major articulator.
[-consonantal]	Involving a closure to the degree [-consonantal] by the major articulator.
[+continuant]	Involving a closure to the degree [+continuant] by the major articulator.
[-continuant]	Involving a closure to the degree [-continuant] by the major articulator.

All of the terminal features retain their traditional property of being able to be specified as either plus or minus. Thus, unlike class features, terminal features may spread a minus value, and they may branch in a contour segment to a sequence of minus and plus, or plus and minus.

4.3 Residue

There remain a few features I have not dealt with in this thesis and whose position in the hierarchy is not obvious. These are the traditional "manner of articulation" features [sonorant], [strident], and [lateral]. These are not directly analogous to [consonantal] and [continuant], because they need not necessarily refer to the degree of closure of an articulator.

For example, although [+sonorant] entails a certain lack of constriction among non-nasal, non-lateral consonants, nasal consonants may be both [-cont] -- i.e. fully constricted -- and [+sonorant], as may laterals. And [-sonorant] entails not only a certain minimal constriction for either labial, coronal, or dorsal, but also entails [-nasal]. Thus, sonorant should not be represented with [continuant] and [consonantal] on the root node, because features on the root node are interpreted as specifying the degree of closure of the major articulator, and [sonorant] does not simply specify degree of closure. Rather, it corresponds to a disjunction of properties. That is, [+sonorant] corresponds to either (i) having degree of closure for a major articulator not so radical as to impede spontaneous vibration of the vocal cords in neutral position or (ii) regardless of the degree of closure of the major articulator, allowing spontaneous vocal cord vibration by (iia) opening a secondary air passage through the nose or (iib) allowing sufficient air to pass around the sides of the tongue despite radical degree of closure of the major articulator. [-sonorant] corresponds to both (i) having degree of closure for a major articulator radical enough to impede spontaneous vibration of the vocal cords in neutral position and (ii) having no secondary air passage either through the nose or around the sides of the tongue.

[lateral] has traditionally been supposed to apply only to coronals. See, for example, Steriade (1986) for arguments to that effect. If it were true that only coronals could be lateral, then we could represent [lateral] under the coronal articulator in the hierarchy. However, non-coronal laterals have been attested in certain languages, for example Zulu and many New Guinean languages (Ken Hale, p.c.). These non-coronal laterals are formed with a dorsal constriction which is released laterally. Thus, since [lateral] may apply to either coronals or dorsals, it cannot be represented under the coronal node. Rather, it should be represented under either the place node, the supralaryngeal node, or the root node.

Finally, [strident] is clearly a feature referring to certain acoustic properties -- i.e. "greater noisiness" (SPE p.329).

Chapter 5

ASSOCIATION LINES

In this chapter, I argue for the assumptions made in Chapter One that association lines represent the relation of overlap in time, and that the ill-formedness of crossing association lines derives from that and other relations among the elements in a phonological representation, rather than being stipulated as a well-formedness condition in UG. Thus, I show that by taking factors external to language intc account -- i.e. knowledge of the world -- we can not only simplify the representation of our knowledge of language (by removing the well-formedness condition from UG), but we can explain why representations in phonology must be such that association lines do not cross. It is not an arbitrary aspect of language.

5.1 Introduction

The introduction of autosegmental levels of representation in Williams (1971) and Goldsmith (1976) made necessary a formalism for representing the coordination in time of the units on the various levels. The formalism chosen was to link the levels together with "association lines", as in (1):

5.1 Introduction

(1)
```
F       G       H   I        level n
|      / \       \ /         association lines
x1   x2   x3      x4         level m
```

Association lines, like syntactic indices, are not linguistic objects. Rather, like indices, they serve only as a convenient way of representing a certain relation between the units that they link.[1] However, except for Goldsmith's (1976) statement that association lines represent "simultaneity in time" (p.42), most phonologists assume the formalism of association lines without making explicit what relation they consider association lines to represent.

It is also assumed in most current work (e.g. Pulleyblank (1983), Archangeli (1984)) that Universal Grammar (UG) includes the well-formedness condition on association lines proposed by Goldsmith (1976):

(2) Association lines do not cross. (p. 48)

However, given that association lines are not themselves linguistic objects, it is undesirable for UG to contain any well-formedness condition like (2) which specifically governs the distribution of association lines. If a well-formedness condition is necessary, it should be stated on the linguistically real relation, and not on the conventional formalism for representing that relation. Furthermore, to state (2) as an independent

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1. Chomsky (1984 class lectures) discusses this point with respect to syntactic indices. Given that association lines are relations, not objects, a rather questionable use of association lines is the one common in tone rules, but used also in many segmental rules, of referring to "rightmost link", "leftmost link", "only link", etc., by symbols such as

```
|✗     ✗|     ✗|✗
x       x       x, respectively.
```

principle of UG is to claim that the fact that association lines do not cross is an arbitrary aspect of UG, and that UG would be simpler if association lines could cross or not cross at will.

In this chapter, I define the relation that association lines represent, and I show that no well-formedness condition like (2) is necessary in UG. The fact that representations involving crossing association lines are always ill-formed is not arbitrary and need not be stipulated, because it derives from basic, independently necessary assumptions about the properties of the relations encoded in a phonological representation.

5.2 Relations and Representations

5.2.1 Precedence

An idiosyncratic property of every word is the order of its segments; therefore, one of the relations encoded in a phonological representation must be precedence in time.[2] Phonologists, by convention, represent precedence relations by left-to-right order on a single line. The

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2. It has been proposed (Goldsmith (1976), Clements (1986)) that a primary relation in phonology is adjacency. However, whether adjacency is available for phonology or not, phonology must make use of precedence. Words are memorized in terms of the order of their segments, not only their adjacency, and most rules take place if something _precedes_ or _follows_ something else; mirror image rules, which are concerned only with adjacency, are rarer. Thus, most of the cases in which Clements or Goldsmith would use adjacency may be covered by immediate precedence: $a < b$ and there is no c such that $a < c$ and $c < b$.

introduction of multiple levels, or tiers, of representation is simply a way to allow some parts of a representation to be unordered with respect to other parts. Lack of ordering is represented by placing the unordered elements on a separate tier, as in (3a) below. In (3a), there is an ordering among F,G,H,I and a separate ordering among x_1,x_2,x_3,x_4, but there is no ordering between {F,G,H,I} and $\{x_1,x_2,x_3,x_4\}$. The representation in (3a) encodes only the precedence relations given in (3b).

(3)

a.	F G H I	tier n	b.	F < G, G < H, H < I
	x_1 x_2 x_3 x_4	tier m		$x_1 < x_2$, $x_2 < x_3$, $x_3 < x_4$

Precedence in time is a general concept, i.e., it applies outside of language, also. Thus, its properties, given in (4), need not be defined in UG, because they are part of our knowledge of the world.

(4)

PRECEDENCE (<)	a.	<u>Transitivity:</u>	if A < B, and B < C, then A < C
	b.	<u>Antisymmetry:</u>	if A < B, then NOT B < A
	c.	<u>Antireflexivity:</u>	NOT A < A

5.2.2 Association Lines

Consider now the relation that is encoded by association lines. Association lines were introduced originally as a representation for coordination in time. Thus, the simplest assumption would be that association lines represent simultaneity in time, as proposed by Goldsmith (1976). Under this assumption, when we draw association lines between the two levels as in (5a), we add the relations of simultaneity given in (5b):

(5) a.

$$\begin{array}{cccc} F & G & H & I \\ | & | & | & | \\ x_1 & x_2 & x_3 & x_4 \end{array}$$

b. $F = x_1$, $G = x_2$, $H = x_3$, $I = x_4$

5.2 Relations and Representations

Since simultaneity in time is, like precedence, a general concept, its properties are included in our knowledge of the world. In particular, simultaneity is transitive, symmetric, and reflexive, and if two elements are simultaneous, then substituting one element for the other in any statement of precedence will not change the truth of that precedence statement. Formally:

(6)

SIMULTANEITY (=)	a.	<u>Transitivity:</u>	if $A = B$, and $B = C$, then $A = C$
	b.	<u>Symmetry:</u>	if $A = B$, then $B = A$
	c.	<u>Reflexivity:</u>	$A = A$
	d.	<u>Substitution:</u>	if $A = B$, and $B < C$, then $A < C$

For example, substitution derives from (5) the precedence statement: $F < x_2$.

The assumption that association lines represent simultaneity leads to two problems when it is applied to multiply-linked structures such as (7a,b):

(7) a.

```
F   G
 \ /
  x
```

b.

```
   F
  / \
x1   x2
```

(7a) is a contour segment, e.g. an affricate. A contour segment is represented as in (7a) to capture the fact that, phonologically and phonetically, it is a sequence of articulations (F and G) within a single segment (x). (7b) is a geminate: one articulation (F) with the length of two segments (x_1 and x_2). Among the motivations for representing geminates as in (7b) are (i) to allow the characterization of geminates as single units for quality-sensitive rules (referring to the feature tier), but as two units for prosody-sensitive rules (referring to the skeletal or x-tier); and (ii) to explain the inalterability effects which geminates and assimilated clusters show (failure of epenthesis rules to split geminates, failure of otherwise applicable rules to apply to only half of a geminate).[3] (7a,b) encode the precedence and simultaneity relations in (8a,b), respectively:

(8)
a. $F < G$, $F = x$, $G = x$ b. $x_1 < x_2$, $F = x_1$, $F = x_2$

The first problem that simultaneity leads to is that by substitution we may derive from (8a,b) the reflexive precedence statements in (9a,b), respectively:

(9) a. $x < x$ b. $F < F$

Since precedence is antireflexive (NOT $x < x$), (9a,b) are impossible: they contradict an inherent property of the precedence relation.

The second problem is that since simultaneity is transitive and symmetric, we may derive from (8a) the statement in (10a) that F is simultaneous with G (since $F = x$ and $x = G$). But F and G are not simultaneous -- F precedes G, so we have derived a contradiction. Similarly, (8b) leads, through transitivity and symmetry, to the contradiction in (10b):

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3. See Hayes (1984), Steriade and Schein (1984), McCarthy (1985) on inalterability. The correlation between quality and prosody rules and the behavior of geminates as one or two units, respectively, was first noted by Kenstowicz (1970). Note: in this paper, when F, G, etc. are on the same tier, they stand for different values of the same feature, e.g. [-cont] and [+cont]; when F, G, etc. are on different tiers, they stand for different features, e.g. [-cont] and [+voice].

(10) a. $F = G$ b. $x_1 = x_2$

A third problem for simultaneity is presented by discontinuous multiply-linked structures like (11a) in the non-concatenative morphology of Semitic or (11b) in the long-distance vowel harmony of Yawelmani:

```
(11)  a.   k     t     b              b.   [+round]
           |     |     |                     / \
           x1 x2 x3 x4 x5                   V C V
              |_____/
              a
```

In the structure in (11a), the features for each morpheme are entered on a separate tier and linked, sometimes discontinuously, to the skeleton. Such structures have been motivated for languages with non-concatenative morphology, e.g. the Semitic languages, based on (i) cooccurrence restrictions within roots, (ii) across the board applications of quality-sensitive rules, and (iii) OCP-antigemination effects. Discontinuous multiply-linked structures also arise in long-distance harmony, as in (11b), where they may show the same across-the-board results.[4]

Among the precedence and simultaneity relations encoded by (11a) are those in (12):

(12) a. $x_2 < x_3$, $x_3 < x_4$ b. $/a/ = x_2$, $/a/ = x_4$

However, from the relations in (12), antisymmetry and substitution derive the contradiction in (13):

----

4. See McCarthy (1985) and references cited there for discussion of these motivations wrt. non-concatenative morphology; see Archangeli (1984) on long-distance harmony.

(13) $/a/ < x_3$ (by substitution into $x_2 < x_3$)

NOT $/a/ < x_3$ (by antisymmetry on $x_3 < x_4$, followed by substitution)

These contradictions in contour, geminate, and discontinuous multiply-linked structures show that association lines do not represent simultaneity between features and x-slots.

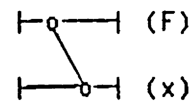
What, then, is the relation that association lines do represent? Consider again the contour and geminate structures in (14a,b) (= (7a,b)).

(14)

Besides the contradictions noted above, there is a basic problem with simultaneity in (14a,b) that has until now gone unnoticed. This problem is simply that, in fact, F is not simultaneous with x in (14a) because F and x are not coextensive in time: x continues in time after F stops. Similarly, in (14b), F is not simultaneous with x_1 because F continues after x_1 stops. Rather, the relation between F and the skeletal slots in such structures is one of partial simultaneity, or overlap in time. I propose, therefore, that overlap in time, not simultaneity, is the relation that association lines represent. Overlap is consistent with F and x not being coextensive in time in (14), while still capturing the fact that association lines imply some degree of coordination in time. Furthermore, as I will show below, overlap avoids the contradictions that simultaneity leads to.

First, what does it mean for a feature F and an x-slot to overlap? It means that some part of the feature and some part of the x-slot are simultaneous. However, which parts are simultaneous, and how large tho parts are, are left undetermined: all that overlap requires is that at least one instant of time be shared between the feature and the x-slot. When F overlaps x, that means that at least one point P(F) in F and one point P(x) in x are simultaneous. Thus, the overlap between F and x that is represented by the association line in (15a) is equivalent to simultaneity between P(F) and P(x), as represented in (15b).[5]

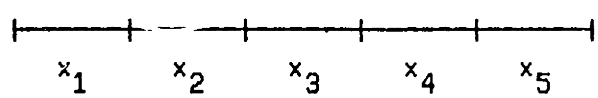
(15) a. F
|
x

b. 

The simultaneity in (15b) differs from the simultaneity proposed by Goldsmith which led to the problems above in that it links, not features to x-slots, but points within features to points within x-slots.

This interpretation of association lines requires a level of detail below the feature and x-slot level. Features and x-slots are no longer unanalyzable units, as in (16a), but instead are made up of points of time, like sections of a time line, as in (16b):

(16)
a. x_1 x_2 x_3 x_4 x_5

b. 

An advantage of viewing features and x-slots as in (16b) is that it captures the fact that features and x-slots are not instantaneous, but occupy some amount of time. For x-slots, this fact follows from their role as timing units, but even features, which might seem to be independent of

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5. I am grateful to J. Higginbotham for suggesting I reexamine overlap and for his suggestions regarding its formal implementation.

timing, still require certain minimal durations for their pronunciation (see section 1.2 above on inherent durations and "incompressibility" of articulations).

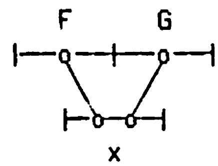
Thinking of features and x-slots as made up of points of time will require a redefinition of how precedence and simultaneity apply in phonological representations. "x_1 precedes x_2" will now mean "all the points in x_1 precede all the points in x_2". Similarly, "F is simultaneous with x" will now mean "every point in F is simultaneous with some point in x, and every point in x is simultaneous with some point in F", i.e., the set of points in F and the set of points in x are coextensive in time. Precedence and simultaneity among features and x-slots I will call "total precedence" and "total simultaneity". In addition to total precedence and simultaneity, there exist precedence and simultaneity relations among points of time. The latter are simply the relations whose properties were given in (4) and (6) (and in terms of which total precedence and simultaneity are defined).

It was assuming association lines to represent total simultaneity that led to the three contradictions above. These contradictions disappear if we instead define association lines as representing overlap among features and x-slots (equivalent to simultaneity among points of time within the features and x-slots being linked).

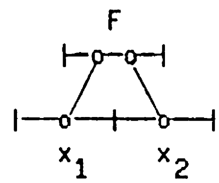
The first problem with total simultaneity was that with the contour and geminate structures (7a,b), it led to the reflexive precedence statements "$x < x$" and "$F < F$", respectively. This problem no longer exists, because (7a,b) (equivalent to (17a,b)) now encode the relations in (18a,b), respectively:

(17)

a.



b.



(18)

a.	All P(F) < all P(G)	b.	All $P(x_1)$ < all $P(x_2)$
	Some P(F) = some P(x)		Some P(F) = some $P(x_1)$
	Some P(G) = some P(x)′		Some P(F)′ = some $P(x_2)$

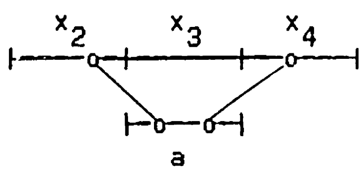
In (17a), points within F and G are both simultaneous with points within x, but they need not be simultaneous with the same point within x. As long as they are not simultaneous with the same point, substitution will not yield a reflexive precedence statement. The same holds for (17b). Rather, substitution derives the statements in (19a,b), respectively:

(19) a. P(x) < P(x)′ b. P(F) < P(F)′

The second problem, that of deriving the false statements "F = G" and "$x_1 = x_2$", is similarly solved. These contradictions were derived by transitivity (if F = x and x = G then F = G). But since now the points in x with which F and G are simultaneous are not identical (and the points in F with which x_1 and x_2 are simultaneous are not identical), transitivity does not apply. (P(F) = P(x) but P(x)′ = P(G).) Another way of looking at this is at the level of features and x-slots (rather than points), where overlap is not a transitive relation: F overlaps x and x overlaps G but that doesn't derive that F overlaps G since overlap is not transitive.[6]

The third problem with total simultaneity, that of the discontinuous multiple linking, is also solved. The discontinuous multiple linking in (11), equivalent to (20), now encodes the relations in (21):

(20)



(21) All $P(x_2) < $ all $P(x_3)$, all $P(x_3) <$ all $P(x_4)$.

Some $P(a) =$ some $P(x_2)$, some $P(a)' =$ some $P(x_4)$.

Substitution yields:

(22) $P(a) <$ all $P(x_3)$, all $P(x_3) < P(a)'$

Since P(a) need not be the same point as P(a)', there is no contradiction.

This view of features and x-slots as made up of points of time, and of association lines as specifying merely overlap, not simultaneity, has interesting consequences for issues such as the relative timing of the different articulations in a segment. The view of x-slots and features I have proposed provides a framework on which such timing relations may be represented, at the level of phonetic implementation. I assume that the points of time within a feature or x-slot are accessible only at the late level of phonetic implementation, where quantitative rules may apply, and that they are not manipulable or accessible by phonological rules. This

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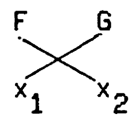
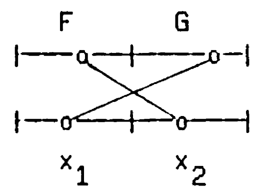
6. The properties of overlap are reflexivity and symmetry, but not transitivity.

proposal is discussed further in Chapter Six.

5.3 Eliminating the Well-Formedness Condition

Consider now a representation such as (23a) (equivalent to (23b)), in which the association lines cross. (23a) encodes the precedence and simultaneity relations in (24a-d):

(23) a. 

b. 

(24) a. All P(F) $<$ all P(G)

b. All $P(x_1)$ $<$ all $P(x_2)$

c. Some P(F) = some $P(x_2)$

d. Some P(G) = some $P(x_1)$

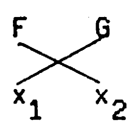
By substitution of (24c,d) into (24b) we may derive (25):

(25) Some P(G) $<$ some P(F).

But (25) contradicts (24a), which states that every P(F) precedes every P(G). Therefore, since we know that substitution preserves truth conditions, it must be that the original set of precedence and simultaneity relations in (24) contains internal contradictions. Thus, the representation in (23), which encodes that set of relations, is ill-formed -- not because of any physical or geometric property of the representation itself, but simply because the relations it encodes are contradictory. I thus account for the ill-formedness of (23) without using any explicit well-formedness condition, much less one referring to association lines.[7]

Consider now the Well-Formedness Condition that I have eliminated. Assuming that association lines represent overlap in time, the Well-Formedness Condition in (2) could be paraphrased as "relations of overlap in time do not cross." But what would it mean for overlap relations to cross? Cross relative to what? Outside of the context of certain assumptions about the representation of precedence and overlap, (2) is meaningless. Only if we assume that (i) precedence relations are represented by left to right order on a single line, (ii) absence of precedence relations is represented by placing elements on a separate line, and (iii) relations of overlap in time are represented by association lines, is it true that in a representation that encodes a coherent set of relations, association lines will not cross. If any of these assumptions is dropped, then association lines may cross without causing a logical contradiction. If, for example, in (26),

(26)



we assume no ordering between F and G, but do between x_1 and x_2, then (26) simply encodes [GF]. It is not an inherent, geometric property of association lines that they can't "cross" -- only of association lines as a

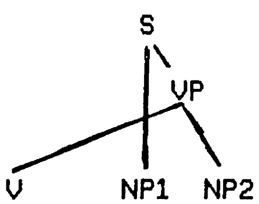
----

7. Not all "lines" in phonological representations are association lines. I have derived here that association lines, which encode overlap in time, do not cross. However, there also exists metrical structure, whose lines encode dominance rather than overlap. The ill-formedness of crossing metrical lines must be derived separately, possibly from a prohibition against overlapping domains. Whatever the derivation, it will have to allow ambisyllabicity, where one segment belongs to two domains.

formalism for overlap in time, together with left to right order as a formalism for precedence.[8] Once the assumptions on which the Well-Formedness Condition depends are made explicit, it becomes clear that the proposed condition is equivalent to "overlap relations may not contradict precedence relations". But this is just a special case of the general (cognitive) requirement that the set of relations associated with an utterance be coherent, and not contain internal contradictions. Thus, I have not simply replaced the Well-Formedness Condition by introducing some other Well-Formedness Condition into UG. Rather, I have eliminated it from UG altogether, because the requirement it derives from is extralinguistic, and so need not be stipulated in UG.

8. Note that "crossing" lines are now considered well-formed in some syntactic analyses, although for a long time, syntactic trees such as (i) were considered ill-formed because "the lines crossed".

(i)



(ii)

S	dominates	VP
S	dominates	NP1
VP	dominates	V
VP	dominates	NP2
V	precedes	NP1
NP1	precedes	NP2

By factoring out of tree structures the relations they encode, as in (ii), Higginbotham (1983) (citing earlier work by McCawley) shows that if the subject NP1 and the VP are not ordered, a tree like (i) is perfectly well-formed, and a previously unavailable analysis of VSO languages becomes possible. (In a language like English, the subject NP and the VP must be ordered, so a structure like (i) is impossible.) The lines in a syntactic tree are not linguistic objects -- they are merely encodings of the dominance relation. And as long as the set of dominance and precedence relations is well-formed, the tree specifying those relations is also, whether the lines "cross" or not.

5.4 Comparison with Goldsmith's Formalization

I have argued above that the widely adopted Well-Formedness Condition (WFC) in (2) is not necessary in UG. However, Goldsmith does not propose (2) as the final version of his WFC. In this section, I will compare my analysis with Goldsmith's final WFC to see whether his formal version avoids the unnecessary stipulation of (2).

Goldsmith's entire WFC, of which (2) is a part, is (informally):

(27) a. All vowels are associated with at least one tone.
All tones are associated with at least one vowel.

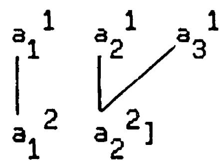
b. Association lines do not cross. (1976:48)

(Only (27b) is currently assumed, since Pulleyblank (1983) has shown that (27a), which causes automatic tone spreading and creation of contour tones, is incorrect.)

The reader may consult Goldsmith (1976:50-53) for a complete explanation of the final, formal WFC that he proposes. What concerns us here is that the formal WFC rests on the assumption that in addition to the elements on each level being ordered, the association lines between those levels themselves form an ordered sequence:

> Each autosegmental level is a totally ordered sequence of elements, a_j^i, [where a_j^i] is the jth element on the ith level. ... In addition to these two sequences of segments, there is a totally ordered sequence of pairs -- essentially the

association lines, from the geometric point of view: (a_1^1, a_1^2) (a_2^1, a_2^2) (a_3^1, a_2^2) ..." (Goldsmith (1976:50)) [where these ordered pairs refer to the structure:



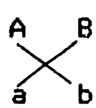
]

Thus, Goldsmith has just replaced the stipulation that association lines do not cross with the stipulation that the sequence of association lines is totally ordered. In addition, Goldsmith introduces a projection function π_i and an inverse projection π_i^{-1}, with an explicit WFC statement in UG that "π_i and π_i^{-1} preserve connectedness" (p.51).

Goldsmith's formalism is intended to account for both clauses of (27) with a single requirement. However, the formalism that Goldsmith proposes does not have exactly the same effects as the informal statements in (27). Rather, as Goldsmith notes, it has the effects in (28):

(28) a. unattached elements are allowed at the periphery

b. association lines may cross in a structure like



(cf. Goldsmith, (1976:93-4)

In footnotes, Goldsmith chooses (28a) over (27a),[9] and he maintains that the difference between (27b) and (28b) is moot because "in every possible linguistic case, there will be at least three segments on some

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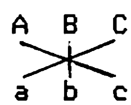
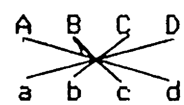
9. Recall that Pulleyblank has shown (27a) to be incorrect anyway.

line, and there [the formal version of the WFC] works correctly" (1976:94).[10] However, structures with just two elements on each level do occur, as in (29), so the fact that Goldsmith's formalism does not prevent crossing association lines in such structures is a problem.

```
(29)   [ igba ]        [ìgbá] "garden egg" (Pulleyblank 1983:123)
       [ |  | ]
       [ L  H ]
```

Moreover, even where there are at least three elements on each line, there are cases of crossing association lines that Goldsmith's WFC cannot rule out. For example, (30a,b) are not ruled out by the formal version of Goldsmith's WFC, for the same reason that (28b) is not ruled out.

(30) a.


b.


Goldsmith's formalism will allow (30a) because (30a) has the "ordered sequence of pairs" (A,c) (B,b) (C,a), the "projections" of which are "connected".

Goldsmith doesn't specify how his formalism would apply in cases of three levels. However, since he requires every (nonperipheral) element on every level to be linked to something, disallowing, e.g.,

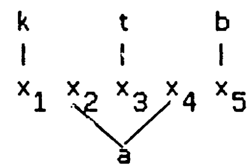
```
(31)   H       L
       |       |
       V   V   V,
```

----

10. Goldsmith also says that in order to rule out the structure in (28b), we would have to assign an "inherent sense to each level, not just total ordering" (1976:94). It is unclear what Goldsmith means by an "inherent sense". In any case, I have shown above that total ordering (= precedence) on each level <u>is</u> sufficient to rule out (28b).

then a structure like (32) for [kətab] would necessarily be ruled out because of the non-peripheral elements which fail to be linked on certain levels (x_3 on /a/'s level, and x_2 and x_4 on /ktb/'s level).

(32)



In summary, Goldsmith's formalization of his WFC cannot deal with discontinuous multiple linkings like those in Semitic, and it contains a serious loophole which allows structures like (28b) and (30a,b). Furthermore, it relies on several assumptions not needed in my analysis, including an assumption of total ordering of the association lines, thus begging the question of whether association lines may or may not cross. Finally, it still requires an explicit Well-Formedness Condition in UG.

5.5 Conclusion

I have shown in this chapter that the ill-formedness of a representation involving crossing association lines follows from (i) what our knowledge of the world tells us about the properties of precedence and simultaneity, (ii) the precedence relations of a given form, which must be learned in any case, and (iii) the proper definition of the relation represented by association lines (overlap, not total simultaneity), which definition is necessary in any analysis. Thus, lack of crossing association lines is derivable from knowledge of the world together with independently necessary aspects of words, and it need not be stipulated in Universal Grammar.

Chapter 6

PHONETIC REPRESENTATIONS

It is a common argument in phonological analyses, and a proper one, to disregard aspects of phonetic realization which are predictable (within the language). For example, in English all vowels preceding nasal consonants are slightly nasalized. Because this nasalization always occurs in the nasal environment and hence is totally predictable, it does not constitute part of the phonology of English (i.e. there are still no phonological nasalized vowels in English), but rather part of the phonetic implementation system for English (in the sense of Liberman and Pierrehumbert (1985)). Processes which occur at the level of phonetic interpretation have certain defining characteristics. They are usually variable in effect, rather than binary. The nasalization in the English example may be of varying degrees, for example. Also, phonetic interpretation processes are automatic in the sense that speakers of a language find these processes much harder to supress than phonological processes. It would be very difficult for an English speaker to pronounce a totally non-nasal vowel before a nasal consonant. Thus, the distinction between phonological processes and phonetic interpretation is a valid one. Nevertheless, the fact that phonetic interpretation can be demonstrated to occur in a different level, or even a different component, of the grammar does not absolve phonologists from accounting for its effects. Too often, characterizing a process as occurring in phonetic implementation serves as an excuse for ignoring the process altogether.

In this chapter I discuss the representation of certain processes that occur at the level of phonetic interpretation. I argue that representations at the level of phonetic interpretation differ in significant ways from the phonological representations we have examined up to this point. One contrast between phonetic and phonological feature representations concerns the representation of degree of closure. I have shown above that in phonological representations, there can be only one specification of degree of closure per root node, which must be represented outside the place node. However, at the level of phonetic interpretation, there can be several specifications for degree of closure -- one for each articulator -- and those specifications may be represented inside the place node, on the relevant articulator node.

Another difference between phonological and phonetic representations concerns the specification of relative timing relations. I have demonstrated in the previous chapter that because association lines represent the relation of overlap in time, which is definable only over non-instantaneous units, x-slots and features which are linked by association lines must have internal duration. I have represented them as being made up of points of time, like intervals of a time line. However, that internal structure is not accessible to phonological processes. Rather, x-slots and features behave with respect to the phonology as unanalyzable units. It is at the level of phonetic representation that the internal durations of x-slots and features first become available for manipulation. In the following sections, I discuss some processes of phonetic interpretation which crucially require these enrichments of representation: degree of closure features for each articulator, and sub-segmental duration.

6.1 Degree of Closure of Minor Articulators

In Chapter Three, I argued that separate degrees of closure for individual articulators are not needed in the phonological representation because whenever the degrees of closure of two articulators in a segment differ, one of those degrees of closure is always predictable (the degree of closure of the minor articuator), and hence need not be phonologically specified in the language. However, the degrees of closure of minor articulators are not universally predictable. On the contrary, we find a continuum from Nupe, which has the universal default of [-consonantal] degree of closure for minor articulations; to Shona, whose dialects show either [+cont] degree of closure or free variation ranging between [-consonantal] and [-continuant] for minor dorsal articulations; to Kinyarwanda, which has [-cont] degree of closure for minor dorsal articulations regardless of the phonological degree of closure of the segments they occur in.

Although these predictable (within a language) degrees of closure are rightly excluded from the phonological representation, which exclusion allowed us to avoid the creation of a new typological category for languages -- i.e. having or not having degree of closure for each articulator, the fact remains that languages differ as to the phonetic degree of closure of minor articulators. Thus, at some point it needs to be specified that in Kinyarwanda the minor dorsal articulation is [-cont] while in Nupe it is [-cons]. The proper level at which to represent these differences is at phonetic interpretation.

In Kinyarwanda, for example, it must be represented that the minor dorsal articulation in [skw] is phonetically [-cont], and the minor labial articulation [-cons], while the major coronal articulation retains the phonological specification [+cont]. Representing these facts will require a modification of the feature geometry at the phonetic interpretation level, to allow for exactly the structure I have argued is not needed phonologically: separate degrees of closure for each articulator. It makes sense that at this late level, which is closer to the representation forming the instructions to the articulators, the articulators should take on more independence. Ultimately, i.e. in terms of possible physical movements, the articulators are totally independent regarding degree of closure. For the later levels of phonetic representation to allow degree of closure specification for each articulator is simply a reflection of the fact that the degree of closure of the lips is not articulatorily dependent on the degree of closure of the tongue front, etc.

Thus, I propose that the phonological structure for Kinyarwanda labiovelarized /s/, in (1a), is converted into the phonetic structure (1b) by two processes of phonetic interpretation. First, a language-specific

Kinyarwanda process assigns [-cont] to the minor dorsal articulator. Second, the universal default assigns [-cons] to the minor labial articulator.

```
(1)     a.        root                      b.        root
                  /| \                                /| \
                   sup [+cont]                         sup [+cont]
                   |                                   |
                 place                               place
                 /  |  \                             /  |  \
               cor  |  dorsal                      cor  |  dorsal
                   lab                                 lab       \
                   |                                   / \       [-cont]
                 [+round]                      [+round] [-cons]
```

The phonological structure (1a) is a segment with phonologically [+cont] coronal articulation and minor labial and dorsal articulations unspecified for degree of closure. The phonetic structure (1b) is simply a segment with [+cont] coronal articulation, [-cons] labial articulation, and [-cont] dorsal articulation.

I will assume that in all languages, even in simple-segment languages like English, the process of converting the phonological representation into instructions to articulators (via phonetic representation) involves relativizing degree of closure features to each articulator, percolating the phonological degree of closure features from the root node to the relevant articulator node, and specifying phonetically the closure features for each articulator on the articulator node itself. The degree of closure of minor articulations would under this view be specified at the phonetic level in exactly the same manner as the degree of closure of phonologically major articulators, i.e. also on the articulator nodes themselves, and (1b) would instead be represented as (2):

6.1 Degree of Closure of Minor Articulators

(2)

```
                root
                 |
                sup
                 |
               place
              /  |  \
           cor   |  dorsal
          /     lab      \
     [+cont]   / \      [-cont]
              /  [-cons]
       [+round]
```

The representation at the level of phonetic interpretation of all degree of closure features on the articulator nodes they apply to, and, correspondingly, the phonetic representation of all articulators with an accompanying degree of closure, is a reasonable move, given the inherent interdependence between degree of closure and articulator features: degree of closure features cannot be executed except by a particular articulator, while articulator features cannot be executed without being executed to some degree. Thus, at some level between the phonological representation and the instructions to the articulators, it must be true that degree of closure features are specified separately for each articulator. I propose that that level is the level of phonetic representation, derived by rules of phonetic interpretation.

In addition to the relativizing of phonological degree of closure features to the major articulator, the phonetic interpretation of degree of closure occurs in all languages whenever the phonological output involves an articulator with unspecified degree of closure, i.e. a minor articulator. The only difference between languages like Nupe and Shona on the one hand, and languages like English on the other, is that Nupe and Shona happen to allow multiple articulators under the place node in phonological representation, whereas any coarticulation effects in English requiring multiple articulators under the place node occur only in phonetic representation. There is no typological distinction in representation of degree of closure features. All languages are allowed only a single phonological specification of degree of closure, and are allowed phonetic specification of degree of closure independently for each articulator.

What about the arguments against specifying degree of closure for each articulator phonologically? Do these apply at the level of phonetic interpretation? The main argument against specifying degree of closure for each articulator phonologically was that it would make it impossible to assimilate place of articulation features independently of degree of closure features. Do place features assimilate independently of degree of closure phonetically?

Actually, it seems to be the case that phonetic assimilations of place also involve assimilation of degree of closure. For example, low-level assimilations of nasals to following labiodental fricatives result in labiodental nasal fricatives, without complete closure. That is, [+cont] assimilates along with the labial articulation. This occurs in a possible pronunciation of the English word <u>informal</u>, in which the assimilation would be represented as in (3), in phonetic representation:

```
(3)              supra   supra
                  / |      |
        [+nasal]    |      |
                 place   place
                    |      |
                    |    labial
                coronal    |
                         [+cont]
```

6.1 Degree of Closure of Minor Articulators

To see that the place assimilation in <u>informal</u> is phonetic, rather than phonological, compare the derivations of <u>informal</u> and <u>impossible</u>. It is possible to pronounce <u>informal</u> with an alveolar nasal, and it is impossible to pronounce it with a bilabial nasal (*imformal). These two facts show that it has not assimilated phonologically to [f]. On the other hand, <u>impossible</u> must be pronounced with a bilabial nasal, having assimilated to [p] phonologically. Furthermore, recall that we have limited the feature [distributed] to the coronal node. Thus, there is no place of articulation feature to distinguish between a bilabial and a labiodental. Rather, the distinction between bilabial and labiodental articulation is in the feature [continuant], the [-cont] being bilabial and the [+cont] labiodental. This means that in the assimilation of /n/ to [ɱ] in <u>informal</u>, the only way to get labiodental articulation in the nasal is to assimilate, not only labial, but also [+cont]. Spreading just labial would result in a bilabial nasal.

Also, the phonetic assimilation of /n/ to a following glide in English necessarily assimilates the [-consonantal] degree of closure of glide. For example, in the English phrases <u>can you</u> and <u>can we</u>, either no place assimilation occurs, the /n/ remaining coronal and [-cont], or degree of closure is assimilated along with place, as in [kaeỹ yu] and [kaew̃ wi]. This assimilation is shown in (4) for /ny/, at phonetic representation:

6.1 Degree of Closure of Minor Articulators

```
(4)      root    root
          |       |
        supra    supra
        / ǂ------'
       /  |       |
      / place   place
soft-pal  |       |
   |    coronal   |
[+nasal]  |     dorsal
        [-cont]   \
                [-cons]
```

Contrast this example with the phonological assimilation of /n,ñ,m/ to following /w/ in Sierra Popoluca, which results in a complete velar [-cont] nasal, because it spreads just the place features of /w/ (Foster and Foster (1948:10):

(5)	/?an - wih/	[?aŋwih]	'I untied it'
	/?iñ - wiši/	[?iŋwisi]	'your beard'
	/da - m - wə?a/	[daŋ wə?a]	'he could no longer'

Thus, the phonetic representation of degree of closure features for each articulator, which predicts that phonetic assimilations of place will always assimilate degree of closure in addition, seems to be borne out by the evidence.

6.2 Subsegmental Timing

I argued in the previous chapter that the relation that association lines represent, overlap in time, necessarily entails that the units they link (x-slots and features) have internal duration. This may be represented by each x-slot or feature being made up of a sequence of points of time, like an interval of a time line. This structure is not available for any phonological processes. Phonological process deal with x-slots and features as unanalyzable units, linking and delinking only whole x-slots or features. Phonologically, a link between a feature and an x-slot is no more specific than overlap in time. Neither relative order nor simultaneity between two features linked to an x-slot may be specified phonologically.

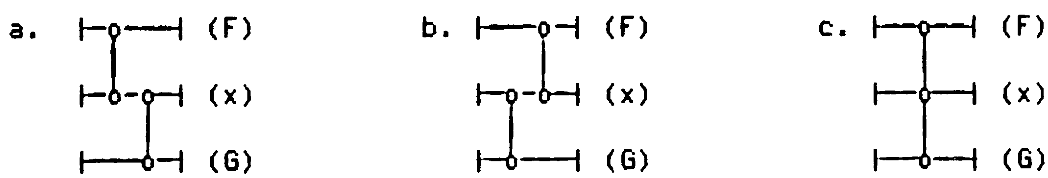
However, although the multiple articulations in a complex segment must be phonologically unordered, as demonstrated in Chapter Two, the fact remains that their phonetic pronunciation, either simultaneous or ordered, is not universally predictable. Rather, just as we saw in regard to degree of closure for minor articultions, each language interprets the ordering or simultaneity of multiple articulations in its own way at the level of phonetic interpretation. These differences in segment-internal ordering must therefore be specified in the phonetic representations.

The internal structure within x-slots and features that was argued to be independently necessary for the proper definition of association lines and for the explanation of why they do not cross provides us with a framework on which we can specify the phonetic subsegmental timing relations among the articulations in a complex segment. That is, I propose that this subsegmental structure, although not accessible phonologically, becomes available for manipulation at the level of phonetic interpretation.

Consider, first, the timing relations among the articulations in a complex segment. Recall that two features linked to the same x-slot are not necessarily simultaneous. Rather, the association lines specify only that each feature will overlap with the x-slot -- there is no specification regarding ordering or simultaneity between the two features themselves. If the two features are unordered, i.e. on separate tiers as in the complex segment in (6) (ignoring intervening structure),

```
(6)     F
        |
        x
        |
        G
```

then they may link to the x-slot in phonetic representation in either order, or simultaneously:

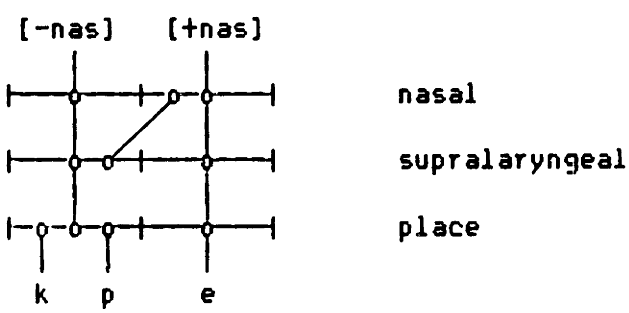
(7) 

The association line itself does not specify either (7a), (7b), or (7c). Linking two features to a single x-slot in a complex segment no more makes those articulations simultaneous than such linking makes the articulations in a contour segment simultaneous.

The fact that the features in a complex segment are not phonologically specified as either simultaneous or ordered explains the somewhat random timing behavior across languages of the articulations within a complex segment. In some languages, the unordered articulations are pronounced simultaneously (or as near to simultaneous as physically possible), e.g. [tkw] in Kinyarwanda [tkwaanga] "we hate". In other languages, they may be pronounced always in a particular order, e.g. [tz?] in Pedi [tz?ɛna] "enter". And in still other languages, there is free variation in the ordering of the articulations, e.g. [ŋw] vs. [mŋ] in Venda [luŋwa] ~ [lumŋa] "be bitten". These inter-language variations arise through different phonetic interpretation processes. Some languages impose regular interpretations on the linkings in (6), e.g. Kinyarwanda interpreting it as in (7c) and Pedi as in (7a,b). Other languages impose no regular interpretation, allowing free variation in the choice of (7a,b,c) as interpretations of (6), e.g. Venda.

A language which orders the labial closure in /kp,gb/ after the velar at phonetic representation is Dan (Santa), discussed by Bearth and Zemp (1967). There are two pieces of evidence for this ordering. First, /kp, gb/ have bilabial implosion. This means that the velar closure must be released before the labial closure; otherwise, the rarification of air produced by the glottis could have no effect on the labial release. (I assume the implosion described is glottal, not velar, i.e. that these are not clicks.) The other evidence for /p,b/ following /k,g/ is that /kp,gb/ are partially nasalized before a nasal vowel, and that that nasalization shows up on the labial articulation rather than on the velar one: /gbẽ/ [gmẽ] 'leg'; /kpẽ/ [kmẽ] 'basement' (p.14). This would be represented as in (8):

(8)



6.2 Subsegmental Timing

The aspects of phonetic representation discussed in this chapter -- independent degrees of closure for each articulator and subsegmental timing -- provide independent support for the phonological representations argued for in the preceding chapters. The need for independent degrees of closure supports the articulator constituents in the hierarchy: labial, dorsal, and coronal. Without the structural representation of different articulators, it would be impossible to specify two degrees of closure within a segment and specify how those degrees of closure should apply to the place of articulation features. The need for a representation of subsegmental timing supports the argument in the previous chapter that association lines represent overlap in time, for only entities with internal duration may overlap.

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